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SIR DOUGLAS MAWSON, KT., O.B.E., B.E., D.SC., F.R.S.

**PROFESSOR SIR DOUGLAS MAWSON, Kt., O.B.E., B.E., D.Sc., F.R.S.  
1882-1958**

The basic biographic data concerning Sir Douglas Mawson are in themselves remarkable. He was born in Bradford, Yorkshire, in 1882, and came to Australia with his parents as a child. He graduated as B.E. from the University of Sydney in 1901 and, after two years' geological work in the New Hebrides, as B.Sc. in 1905. In 1905 he came to the University of Adelaide as lecturer in mineralogy and petrology and was awarded the D.Sc. degree in 1909. In 1907-1909 he was in Antarctica with the Shackleton expedition, and he led expeditions organised by himself to Antarctica in 1911-14, in 1929 and in 1931. It must also be added that his own expeditions were notable for scientific planning and results, and that Mawson himself displayed superlative courage and endurance. Shortly after his return from Antarctica in 1914 he volunteered for army service. He was commissioned as a Staff Officer, and one of his assignments took him to Russia, where he was concerned with the supply of munitions to the eastern front. He was knighted in 1914, and in 1920 he became Professor of Geology and Mineralogy in Adelaide. He was elected a Fellow of the Royal Society of London in 1923 and in 1935-1937 he was President of A.N.Z.A.A.S. He received numerous honours both State and academic from many countries.

These facts alone indicate a remarkable life and remarkable achievement, but they give a quite inadequate picture of the man himself. Combined with the great explorer and scientist and the inspiring leader and teacher was a very human, gentle man. It is possible here to deal with only one or two aspects of his widespread activities, and particularly those associated with the Royal Society of South Australia.

Mawson became a Fellow of the Society in 1905, served as a Councillor in 1941-1942, Vice-President in 1923-1924 and again in 1925-1926, and President in 1924-1925 and again in 1944-1945. He was awarded the Verco Medal in 1931. It was fitting that his election as an Honorary Fellow in 1955 was made in his fiftieth year as a member of the Society.

Shortly after Mawson first came to Adelaide he was attracted by the good exposures and striking nature of the rocks of the Barrier Ranges and the Broken Hill area. The Society recognised the importance of his work in this region by publishing two memoirs, "Chistolites from Bimbowrie, South Australia" and "Geological Investigations in the Broken Hill Area". This form of publication, much more elaborate than the Transactions and now discontinued, was reserved for works of special merit. His work in the neighbourhood of Olary included the first investigation of the Radium Hill deposit and gave him a special interest in the minerals of uranium and other rare metals; an interest he retained actively for the rest of his life. This same interest also first took him to the Flinders Ranges, where he did a great deal of work on the Mount Painter minerals.

Visits to the Barrier and Flinders Ranges, originally undertaken for their mineralogical interest, had shown Mawson that these regions also gave wonderful exposures of Proterozoic glacial rocks. His Antarctic experiences had given him a profound interest in glaciology and it was early in the 1920's that he started his systematic work on the rocks of the Adelaide System in the Flinders Ranges. For thirty years this work continued and a series of papers published in the Transactions of this Society must be regarded as classical contributions to a subject of outstanding geological interest.

The fundamental interests of Mawson are shown by his insistence on the importance of the physico-chemical aspects of geology. Apart from his purely stratigraphic papers most of his work is supported by chemical data. He also encouraged most of his students to become proficient in chemical work.

Although Mawson's contribution to the publications and the official work of the Society has been of outstanding importance, his less formal participation in the meetings of the Society must not be overlooked. He frequently exhibited specimens of unusual interest and entered into discussions with enthusiasm. In this his interests and knowledge were by no means confined to geological subjects but ranged widely. He had a particular knowledge and love of trees and his advice was often sought by his friends.

Those who worked with and knew Douglas Mawson could not fail to recognise the quality of greatness, but they are also grateful to have known a very human and modest and kindly man.

A.R.A.

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# **THE DISTRIBUTION AND FIELD RELATIONS OF THE GRANITIC ROCKS OF PORT ELLIOT, SOUTH AUSTRALIA.**

*BY D.R. BOWES*

## **Summary**

Two closely-spaced intrusive phases of granite are postulated. The first intrusion was contaminated by assimilation of country rock of the roof and is now seen as a porphyritic granite. The second granite, an even-grained type, intruded the porphyritic granite but did not reach the meta-sedimentary roof and so remained uncontaminated.



# THE DISTRIBUTION AND FIELD RELATIONS OF THE GRANITIC ROCKS OF PORT ELLIOT, SOUTH AUSTRALIA.

by D. R. BOWES\*

[Read 10 April, 1958]

## SUMMARY

Two closely-spaced intrusive phases of granite are postulated. The first intrusion was contaminated by assimilation of country rock of the roof and is now seen as a porphyritic granite. The second granite, an even-grained type, intruded the porphyritic granite but did not reach the meta-sedimentary roof and so remained uncontaminated.

The granitic rocks of Port Elliot, some 50 miles south of Adelaide, were investigated by Browne (1920) who described two main types of granite, porphyritic and even-grained, and discussed their general distribution and field relations.

Investigations of the granite mass at Rosetta Head, 6 miles west of Port Elliot, led the present author to postulate successive phases of granite intrusion and the formation of the porphyritic granite by contamination of the even-grained type seen at Port Elliot (Bowes, 1954). The granitic rocks at Port Elliot were also mapped at 24 in. = 1 mile (Fig. 1) and the following are the salient points which emerged from this work.

The *porphyritic granite*, which makes up the major part of the cliffs at Port Elliot, is similar to the granite at Rosetta Head and Granite Island (Browne *op. cit.*) although the felspar phenocrysts are generally smaller and less abundant. Numerous angular xenoliths of meta-greywacke are found and some show metasomatic effects similar to those seen on Granite Island (Kleeman, 1937). The roof of the intrusion is not exposed although it is possible that the large meta-greywacke mass on the western side of Green Bay (Fig. 1) may be a roof pendant.

The *even-grained* outcrops are localized in two areas, *viz.* in the vicinity of Green Bay and at about 600-700 yards N.N.E. of Commodore Point. There is no suggestion of angularity in the shape of any of the masses of even-grained granite, most of the boundaries being arcuate, and no xenoliths of country rock are present. The junction between the two granites is never knife-sharp and it was found virtually impossible to decide between which crystals the contact passes. Neither granite shows a reduction of grain size against the other and some individual crystals at the margin give the appearance of having grown across what may have been an original junction.

The *aplite dykes* and *schorl rock* pipes cut across both granitic types.

It is postulated that the first granite intrusion, at the level exposed, was contaminated near its roof by the assimilation of meta-sediments to produce the porphyritic granite, the magmatic character of which is indicated by the presence of angular disoriented xenoliths. It has been suggested that a similar mechanism produced the porphyritic granite at Rosetta Head and Granite Island (Bowes *op. cit.*) although the larger and more abundant felspar phenocrysts in these places probably resulted from the assimilation of albite- and chlorite-rich rocks.

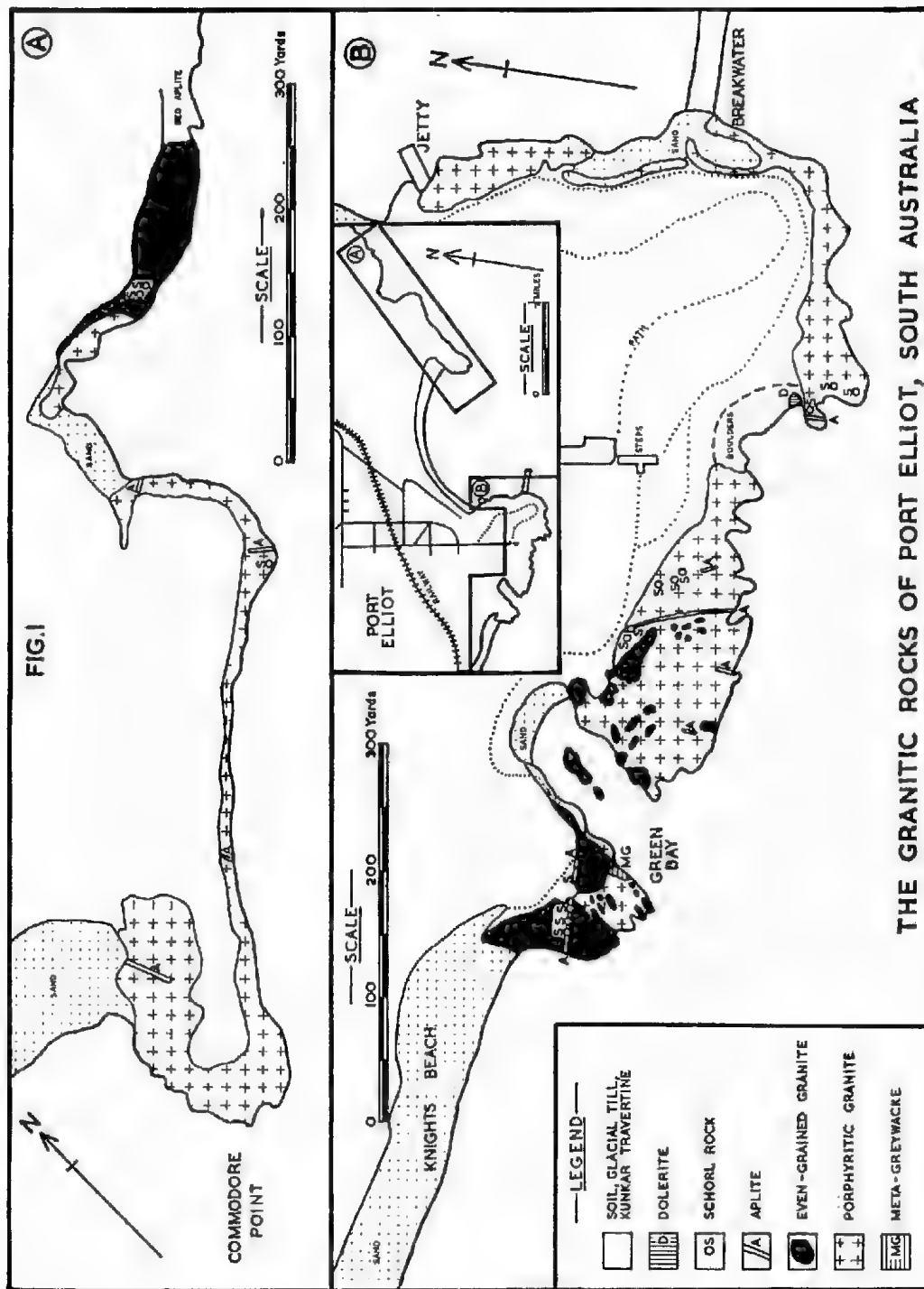
\* Department of Geology, University of Glasgow.

The even-grained granite outcrops near Green Bay (Fig. 1) are postulated as representing the tops of small cupola-like masses intruded into the porphyritic granite. This second granite intrusion, which contains no meta-greywacke xenoliths, did not reach the roof of the first intrusion and so remained uncontaminated. Lack of chilled margins around the even-grained granite, the difficulty of delineating the precise line of contact and the absence of xenoliths of porphyritic granite in the even-grained granite suggest that the earlier intrusion was still hot, possibly a crystal mush with residual magma, when the later intrusion occurred.

The aplite dyke injection and schorl rock formation followed the intrusion of the even-grained granite and it is postulated that they were associated with the late stages of its cooling.

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**SOME ACARINA FROM AUSTRALIA AND NEW GUINEA  
PARAPHAGIC UPON MILLIPEDES AND COCKROACHES AND ON  
BEETLES OF THE FAMILY PASSALIDAE.**

*BY H. WOMERSLEY*

**Summary**

This paper, the second of a series on certain families of Mesostigmata-Trigynaspida (Acarina) paraphagic upon millipedes, cockroaches and Passalid beetles from Australia and New Guinea, deals with the family Fedrizziidae. Twenty species in all are recognised, including two from the Island of Buru, and fifteen are described as new. Two new genera *Neofedrizzia* and *Parafedrizzia* are erected. The species *Toxopeusia*(*Fedrizzia*) *strandi* Oudeinans, 1927, from Buru is regarded as a valid species not conspecific with *grossipes* Canestrini, 1884 from Queensland. *Toxopeusia vitzthumi* Ouds., 1927, also from Burn, is also considered a valid species and placed in the genus *Neofedrizzia* but differing from the other known species. Canestrini's *Fedrizzia luevis* from Queensland is shown to be a species of *Neofedrizzia*.

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South Australian Museum

[Read 8 May, 1958]

**SUMMARY**

This paper, the second of a series on certain families of Mesostigmata-Trigynaspida (Acarina) paraphagic upon millipedes, cockroaches and Passalid beetles from Australia and New Guinea, deals with the family Fedrizziidae. Twenty species in all are recognised, including two from the Island of Buru, and fifteen are described as new. Two new genera *Neofedrizzia* and *Parafedrizzia* are erected.

The species *Toxopeusia (Fedrizzia) strandi* Oudemans, 1927, from Buru is regarded as a valid species not conspecific with *grossipes* Canestrini, 1884 from Queensland. *Toxopeusia vitzthumi* Ouds., 1927, also from Buru, is also considered a valid species and placed in the genus *Neofedrizzia* but differing from the other known species.

Canestrini's *Fedrizzia laevis* from Queensland is shown to be a species of *Neofedrizzia*.

**Pt. 2.—The family FEDRIZZIIDAE.**

(Mesostigmata-Trigynaspida.)

*Toxopeusiidae*, Oudemans, 1927, Ent. Ber. 7(156): 227.

(Type genus and species *Toxopeusia strandi* Ouds., 1927.)

*Fedrizziidae*, Trägårdh, 1937, Arkiv. f. Zool., 29B(11): 5.

(Type genus and species *Fedrizzia grossipes* Canestrini, 1884.)

The species belonging to this family are to be found associated with Carabid beetles principally of the family Passalidae. They are small round to oval strongly sclerotised mites with flatish venter and more raised convex dorsum. The dorsal shield is entire and furnished usually with numerous pores and fine setae, generally so minute and upstanding that only their bases are to be seen and are difficult to distinguish from pores. In most species the anterior of the dorsal shield overlaps the gnathosoma as a hyaline crescent- or sickle-shaped portion devoid of pores or setae except the one pair of vertical setae. In *Neofedrizzia scutata* n. sp., however, this hyaline portion is extended backwards and expanded laterally to form a shield, devoid of pores and with only some minute setae laterally, which covers about two-thirds of the body before it merges with the posterior of the dorsal shield. Anteriorly the shield underlaps the venter to form a camerostome, is confluent marginally with the ventral shield and underlaps again posteriorly to contour the ventral and anal shields. The gnathosoma arises within the camerostome; there are three pairs of hypostomal setae and the labial cornicles are hyaline and thumb-like with a subapical adpressed claw-like process; the palpi are 5-segmented, the basal segment is broad with a pair of long setae on the inner lamella, the specialised tarsal seta is 2-tined; mandibles with both chelicerae dentate, the movable digit with long hyaline processes two of which are blade-like and serrate, the others filamentous;



within the postero-lateral angles of the camerostome is a triangular sclerotised plate (the "axillar" plates of Sellnick *in lit.*) of unknown function. The legs are short, 6-segmented; I is slender, antennaeform without tarsal caruncle and claws; II-IV are stout, the tarsi with pretarsus, caruncle and indistinct claws, femora of leg IV may be elongate without lamellae (*Fedrizzia*) or short and swollen with lamellae and with a stout curved spine at the posterior inner corner (*Neofedrizzia*) or similar but without the stout curved spine (*Parafedrizzia*).

In the female sex the ventral shields consist of a tritosternum with paired laciniae; a single transverse jugular shield separated from the anterior margin of the sternal shield by a transverse suture and furnished with one pair of setae and one pair of pores; a sternal shield which is coalesced with the endopodal shields of coxae I and is much wider than long, the greatest width being across the postero-lateral arms which extend between coxae II and III, it is furnished with three pairs of setae and one pair of pores, the anterior pair of setae (sternal setae II) are in the antero-lateral angles, the other two pairs (sternal setae III and IV) form a transverse row close to the posterior margin; hinged to the posterior margin of the sternal shield is the sternogynial shield which is shaped somewhat like an inverted bell-jar and is furnished with only one pair of pores in the antero-lateral angles; at the posterior apex of the sternogynial shield is the small reduced mesogynial shield; the latigynial shields are long, narrow and strap-like flanking the sternogynial shield from the mesogynial shield to the antero-lateral corners of the sternogynial shield; the ventral shield is large covering most of the venter, medially it extends forward on each side of the sternogynial shield and between this shield and coxae III and IV with the endopodal shields to which it is coalesced, between the outer margins of the body and coxae II-IV it extends forwards and is coalesced with the exopodal shields, peritremal shields and anteriorly with the underlap of the dorsal shield where it forms the camerostome, on the outer body margins it is coalesced or confluent with the dorsal shield, posterior of coxae IV its margins converge inwards for some distance and are separated from the underlap of the dorsal shield by a somewhat diagonal suture, its posterior margin is wide and transverse separated from the anal shield by a transverse suture, it has few if any setae and its surface is in most species of *Fedrizzia* covered by a grid of fine transverse striae crossed by short longitudinal ones, in other species it is quite smooth; the anal shield is wide and triangular with the anal opening in the posterior angle and usually with a few short setae besides a pair of longer paranal setae; the stigmata are situated between coxae III and IV and the peritremes reach coxae I; outside of the peritremes opposite coxae III is the atrium of a large duct, the outer edge of the atrium being strongly sclerotised.

In the male the jugular shield may be present and separated as in the female, or it may be absent. When absent (*Neofedrizzia*) there is in front of the anterior margin of the sternal shield a pair of anteriorly directed processes of unknown function; the rest of the ventral shields except the anal are all coalesced to form a sterno-ventral shield with the genital orifice near the anterior margin between coxae II or between coxae II and III, the surface may be furnished with a grid of fine striae as in the females of some *Fedrizzia*, or it may be smooth; when a grid is present a forwardly curved line indicates fusion of the ventral and sternal portion; the anal shield is similar to that of the female; in *Parafedrizzia* the anal shield is not demarcated, being coalesced with the rest, as it is also coalesced with the ventral shield in the female of this genus.

Hitherto the only genus included in the family has been *Fedrizzia* Caenestri, 1884 (= *Toxopeusia* Ouds., 1927) with *F. grossipes* Caenest., 1884, as type.

In this paper eight species of *Fedrizzia* s. str. are recognised of which six are described as new. Two new genera *Neofedrizzia*, with eleven species, nine of which are new, and *Parafedrizzia* with one new species are erected. Of the previously known species *Fedrizzia* (*Toxopeusia*) *strandi* Ouds., 1927, from the Island of Buru has generally been considered as the same as *grossipes* from

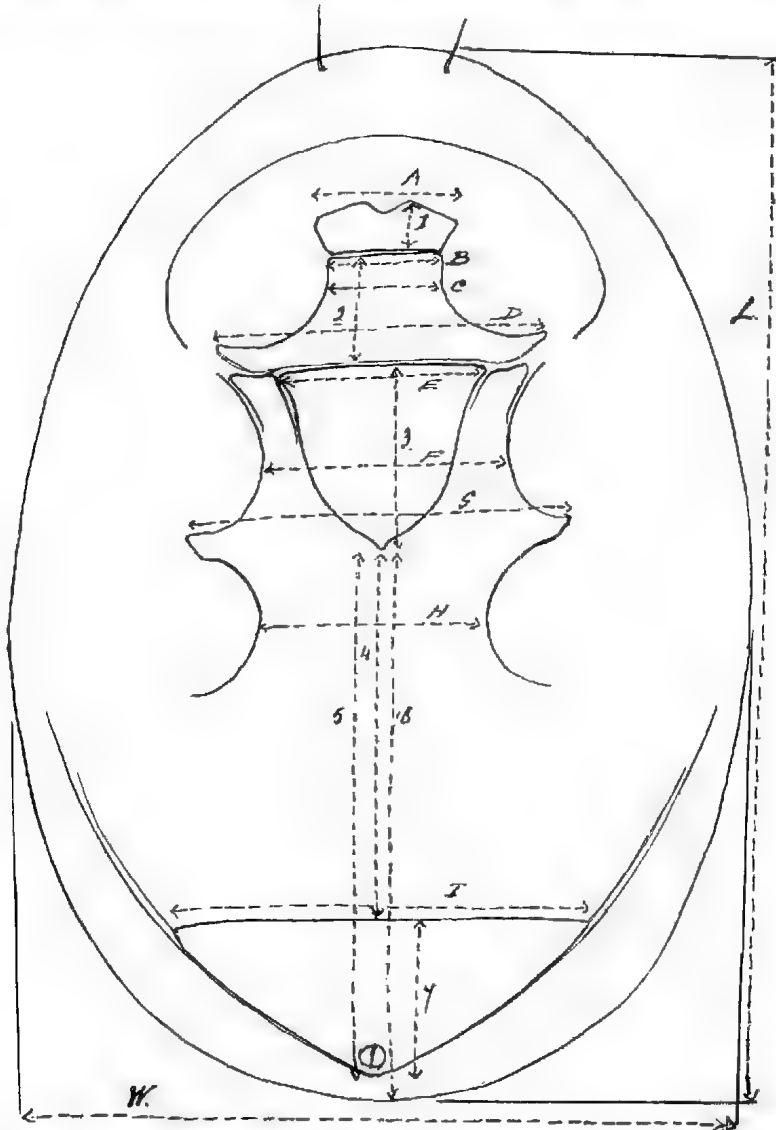


Diagram to illustrate main measurements used: L, length of idiosoma; W, width of idiosoma; 1, length of jugular shield; 2, length of sternal shield; 3, length of sternogynial shield; 4, distance of apex of sternogynial from anterior margin of anal shield; 5, distance from apex of sternogynial to apex of anal shield; 6, distance of apex of sternogynial from end of body; 7, length of anal shield; A, width of jugular shield; B, anterior width of sternal shield; C, width of sternal shield at narrowest part between coxae II; D, greatest width of sternal shield across postero-lateral arms; E, anterior width of sternogynial shield; F, width between coxae III; G, width between points of angles between coxae III and IV; H, width between coxae IV; I, width of anal shield.

Queensland. It is now regarded as a separate and valid species. *Fedrizzia laevis* Canest., 1884, from Queensland is recognised as a valid species of *Neofedrizzia*, as is also *Toxopeusia vitzthumi* Ouds., 1927, from the Island of Buru.

Drs. Camin and Gorirossi in their 1955 paper had before them an undescribed species in which the sternogynial shield was rounded and not tapering as in *grossipes* and in which the male lacked the jugular shield. On these characters they suggest that their material belongs to a new and undescribed genus. It would now seem that they have a species of *Neofedrizzia* as diagnosed in this paper.

That the rounded or tapering character of the sternogynial shield is not a good generic one is shown in the present studies by the occurrence of both forms in both *Fedrizzia* and *Neofedrizzia*.

For the discovery of several features in the morphology of these mites such as the pair of pre-sternal processes in front of the anterior margin of the sternal shield in those species (genus *Neofedrizzia*) in which the jugular shields are absent in the male, and also the presence in the postero-lateral angles of the camerostome of a small well sclerotised triangular plate, as well as for other help and advice I wish to record my grateful thanks to Dr. Sellnick.

Geographically species of this family will probably be found to occur in the tropical and semi-tropical regions wherever beetles of the family Passalidae and its allies occur. So far, however, species have been or are now described from the Moluccas, New Guinea, and the rain forest area of eastern Australia.

The following species are dealt with in this paper:—

Genus *FEDRIZZIA* s. str. Canest., 1884.

<i>grossipes</i> Canest., 1884.	Queensland, Australia.
sp. cf. <i>grossipes</i> Canest., 1884 (Sellnick in lit.)	Queensland, Australia.
<i>sellnicki</i> sp. nov.	Queensland, Australia.
<i>carabi</i> sp. nov.	Aiyura, New Guinea.
<i>derricki</i> sp. nov.	Queensland, Australia.
<i>oudemansi</i> sp. nov.	New South Wales, Australia.
<i>bornemisszai</i> sp. nov.	Queensland, Australia.
<i>strandii</i> (Ouds., 1927)	Is. of Buru, Moluccas.

Genus *NEOFEDRIZZIA* nov.

<i>gayi</i> sp. nov.	Queensland, Australia.
<i>canestrinii</i> sp. nov.	Queensland, New South Wales, Australia.
<i>cynota</i> sp. nov.	New South Wales, Australia.
<i>camini</i> sp. nov.	New South Wales, Australia.
<i>gorirossiae</i> sp. nov.	Queensland, Australia.
<i>tragardihi</i> sp. nov.	New South Wales, Queensland, Australia.
<i>brooksi</i> sp. nov.	Queensland, Australia.
<i>vidua</i> sp. nov.	Queensland, Australia.
<i>scutata</i> sp. nov.	Bulolo, New Guinea.
<i>laevis</i> (Canest., 1884)	Queensland, Australia.
<i>vitzthumi</i> (Ouds., 1927)	Is. of Buru, Moluccas.

Genus *PARAFEDRIZZIA* nov.

<i>buloloensis</i> sp. nov.	Bulolo, New Guinea
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Key to the genera of the family *Fedrizziidae*

1. Jugular shields coalesced medially to form a transverse shield separated from the sternal shield in both sexes. Sternogynial shield rounded posteriorly to bell-jar shape with tapering sides and apical

knob. A triangular anal shield present or not. One of the two long setae on basal segment of palpi with 6-9 long branches, other nude. Femora of legs II-IV elongate and truncheon like or short and wide but without a strong curved spine at posterior angle. <sup>2</sup>

Such jugular shields absent in male being coalesced with sternal shield; in front of sternal with a pair of free or basally fixed forwardly directed processes and the basal part of tritosternum bulbous. Sternogynial shield evenly rounded or bell-jar shaped. Anal shield present. Both long setae on basal palpal segment only shortly ciliated. Femora of legs II-IV short and broadly swollen with lamellae and with a strong curved spine at posterior angle.

Genus *Neofedrizzia* nov.

Type *N. gayi* sp. nov.

2. Anal shield absent, coalesced with ventral shield in both sexes. Elongate species widest behind middle in line of coxae IV. Femora III and IV short and swollen with lamellae, but with only a straight normal seta at posterior corner.

Genus *Parafedrizzia* nov.

Type *P. buloloensis* sp. nov.

Anal shield present in both sexes. Rounded species. Femora III and IV elongate, longer than wide and truncheon like, without lamellae.

Genus *Fedrizzia* Canest., 1884.

Type *F. grossipes* Canest., 1884.

#### Genus FEDRIZZIA Canestrini, 1884

Canestrini, G., 1884. Acari nuovi o poco noti II. Acari dell'Australia—Atti del R. Istituto Veneto 11(6): p. 707.

Type *F. grossipes* Canest., 1884.

—*Toxopeusia* Oudemans, A. G., 1927. Aacarol. Aanteekeningen. LXXXVII. Ent. Ber. 7 (156): 227; Fauna Buruana. Acari, in Treubia 7, Suppl. 2: p. 60.

As differentiated in the preceding discussion and diagnosis of the family and as in the key to genera.

#### *Fedrizzia grossipes* Canestrini, 1884

*Fedrizzia grossipes* Canest., 1884. Atti del R. Inst. Veneto 11(6): p. 707, pl. 8, figs. 1-2.

This species was originally described by Canestrini from specimens found on beetles "allied to the European *Geotrupes*" from Queensland collected by the late Prof. F. Pulle of the University of Padova. Later, in 1927, and more fully in 1928, Oudemans described the genus *Toxopeusia* with *strandii* sp. nov. as type, from "in fungi" from the Island of Buru. This genus is now accepted as synonymous with Canestrini's *Fedrizzia*. In his figures and descriptions of *grossipes* Canestrini shows a moderately elongate oval form which however differs considerably in the ratio of length to width as given by the quoted dimensions, from that shown by his figure. The dimensions quoted in the description are: length in both sexes  $900\mu$ , width of male  $520\mu$ , of female  $530\mu$ , which gives a ratio of approximately 1.70:1.0 for length to width. In the figures, assuming the length to be correct the width would be approximately  $620\mu$  for the male and  $630\mu$  for the female or a ratio of length to width of approximately 1.44:1.0. This consideration suggests that the dimensions given in the text should have been  $620\mu$  and  $630\mu$  respectively.

I am very greatly indebted to my colleague Dr. Max Sellnick of Hamburg who has examined the types of both male and female of *grossipes* which were

sent to him by Dr. Valle Parma, for the following measurements of these specimens:

Type ♀: length of idiosoma  $918\mu$ , width  $612\mu$  (which gives a ratio of length to width 1.5:1.0).

Type ♂: length of idiosoma  $900\mu$ , width  $594\mu$  (which gives a ratio of length to width of 1.51:1.0).

These measurements confirm the view expressed above that the widths given by Canestrini were probably an error in printing.

Other dimensions of the type specimens for which I am also deeply indebted to Dr. Sellnick are:

*Female.*

Jugular shield (tetartosternum)  $120\mu$  wide by  $28\mu$  deep medially.

Sternal shield, length medially  $84\mu$ , width anteriorly  $100\mu$ , width between coxae II (i.e. narrowest part)  $88\mu$ , maximum width of postero-lateral arms  $304\mu$ .

Sternogynial shield,  $124\mu$  long by  $160\mu$  wide anteriorly, distance of posterior edge from anterior of anal shield  $306\mu$  and from posterior edge of body  $486\mu$ .

Ventral shield, distance between coxae III  $196\mu$ , between angles between coxae III and IV  $296\mu$  and between coxae IV  $176\mu$ .

Anal shield,  $324\mu$  wide by  $135\mu$  long (deep) (ratio of width: length = 2.4:1.0).

*Male.*

Jugular shield (tetartosternum)  $80\mu$  wide by ? long.

Sterno-ventral: width between antero-lateral angles  $120\mu$ , between angles between coxae II and coxae III  $288\mu$ ; between angles between coxae III and coxae IV  $280\mu$ , width between coxae II  $84\mu$ , between coxae III  $188\mu$  and between coxae IV  $172\mu$ , distance from anterior border to anterior edge of genital orifice  $60\mu$ , genital orifice  $52\mu$  long by  $72\mu$  wide.

Anal shield:  $320\mu$  wide by  $125\mu$  long (ratio of width: length = 2.5:1.0).

*Fedrizzia* sp. cf. *grossipes* Canest., 1884

Text fig. 1 A-K

Some few years ago I sent to my friend and colleague, Dr. Max Sellnick, of Hamburg, some material of several species of *Fedrizzia* s.l. of which he very kindly made dissections and studied them.

Amongst this material were a number of specimens from a Passalid beetle from Imbil, Queensland (coll. J. F. Gay, 11th Sept., 1946) which, after comparison with the type male and female of *F. grossipes* Canest. received by him from Dr. Valle Parma, he considered (*in lit.*) to be conspecific therewith. A study of Sellnick's dissections and of other entire specimens and a comparison of their detailed measurements with those given to me by him of the types of *grossipes* convinces me that the Imbil specimens are specifically distinct therefrom. In the present study it is shown that the many species of the genera *Fedrizzia* and *Neofedrizzia* are very constant in certain specific characters as follows: (1) overall size which varies but little and which does not differ much between the sexes; (2) the shape, whether more or less rounded or more elongate; (3) the dimensions of the anal shield.

However, in deference to Dr. Sellnick's opinion as expressed in correspondence I refrain for the present from giving a specific name to this species, comparing it with *grossipes* Canestrini.



*Material studied.*—A number of specimens of both sexes from Passalid beetles from Imbil, Queensland, 11th Sept., 1946 (coll. F. J. Gay). Also 2 males and 2 females from Yarramon, Queensland, 29th Aug., 1935, host? (coll. A.R.P.), and

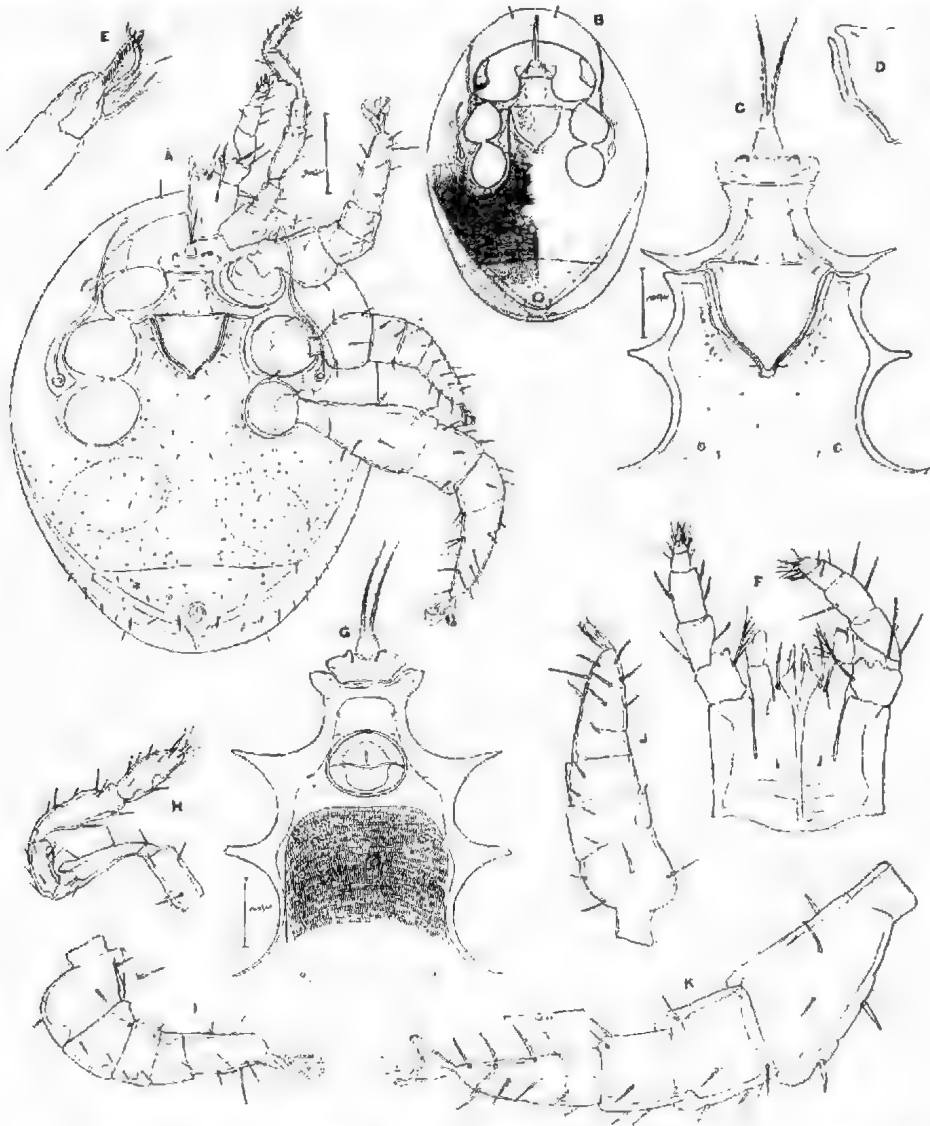


Fig. 1.—*Fedrizzia* sp. cf. *grassipes* Canest., 1884, A-F, H-K Female: A, ventral view; B, venter (after Sellnick) showing camerostome, axillar plates and ornamentation; C, tritosternum, jugular, sternal, sternogynial, and latigynial shields, enlarged; D, latigynial shields separated from sternogynial; E, chelicerae; F, gnathosoma and palpi; H, leg I; I, leg II; J, leg III; K, leg IV; G, Male, tritosternum, jugular and sternal shields.

1 male from *Aulacocyclus* sp. (Passalidae) from Dalby, Queensland, 25th Dec., 1952 (coll. H. Geary). Also 1 male from *Mastochilus dilatus* Dalm., Washpool Crk., near Tenterfield, N.S.W., 8th Oct., 1956 (coll. G. F. Bornemissza).

*Description*—*Female* (from Imbil).—Broadly oval to roundish in shape. Length of idiosoma 1160 $\mu$ , width 870 $\mu$ .

*Dorsum* with numerous small pores or setae bases—if the latter than the setae are exceedingly minute and upstanding.

*Venter*—Base of tritosternum wider than long in the ratio of 10 : 9; jugular shield as figured,  $146\mu$  wide by  $42\mu$  long, with rounded antero-lateral corners, anterior margin straight and only indented medially, the single pair of setae  $25\mu$  long curved backwards and  $61\mu$  apart, the one pair of lyriform pores  $75\mu$  apart and nearer to the posterior than to the anterior border; sternal shield with the anterior margin transverse and  $105\mu$  wide, sides contouring the edges of coxae II and continuing between coxae II and III to a maximum width of  $366\mu$  between the ends of the postero-lateral arms, narrowest part just behind anterior margin  $99\mu$ , posterior margin straight medially for  $150\mu$  then curving posteriorly for a width of  $45\mu$  before running obliquely forwards to the tips of the postero-lateral arms of the shield, shield with three pairs of setae and one pair of lyriform pores, the setae are all short ca.  $10\mu$  long, the anterior pair of setae are  $47\mu$  behind the anterior margin and  $70\mu$  apart, the other two pairs form a transverse row near the posterior border, the medial pair  $38\mu$  apart and  $28\mu$  from each lateral, the single pair of pores are behind the anterior pair of setae  $38\mu$  in front of the posterior margin and  $75\mu$  apart; the sternogynial shield is somewhat like an inverted bell-jar or cone with more or less pronounced apex, it is  $141\mu$  long by  $169\mu$  wide anteriorly, ratio of width to length = 1.2 : 1.0, with the pair of lyriform pores in the antero-lateral angles  $126\mu$  apart; latigynial shields long and strap-like, widening just beyond the middle to the anterior end; mesogynial shield small and reduced; ventral shield as in the generic diagnosis, its posterior margin transverse, straight and  $400\mu$  wide, furnished with many minute setae and pores; anal shield triangular  $400\mu$  wide by  $14\mu$  long, ratio of width to length = 2.86 : 1.0.

*Gnathosoma* as in generic diagnosis.

*Legs*—I  $440\mu$  long, II  $480\mu$ , III  $510\mu$ , IV stout  $812\mu$  (femur elongate expanding gradually to  $164\mu$  wide at apex).

*Male* (from Imbil).—Of the same size and shape as the female.

*Dorsum* as in female.

*Venter*—Jugular shield smaller and narrower than in the female and fitting into a median depression of the anterior margin of the sternal shield, the setae and pores are near the anterior margin, the setae  $36\mu$  apart; sterno-ventral shield as figured and in the genus, anterior margin  $132\mu$  wide with a wide and fairly deep excavation, the width across the arms between coxae II and III  $352\mu$ , and between these and the antero-lateral corners it narrows to  $103\mu$ , it carries anteriorly of the posterior of the genital orifice three pairs of minute setae and two pairs of pores, the anterior two pairs of setae are in front of the orifice and equidistant apart while the third pair is just posterior of the middle of the orifice, the anterior pores are in the antero-lateral angles and the second anterior of the third pair of setae; the rest of the shield behind the orifice has a number of pores and a few minute setae; the genital orifice is large  $75\mu$  long by  $103\mu$  wide and is placed in a line between coxae II and III; the anal shield is as in the female,  $406\mu$  wide by  $139\mu$  long.

### *Fedrizzia sellnicki* sp. nov.

Text fig. 3 A-I

*Types*—Holotype female and allotype male from a Passalid beetle from Mt. Lamington, Queensland, 1946 (coll. <sup>2</sup>), represented by three slides of dissections of each sex made by Dr. M. Sellnick and now in the South Australian Museum.

*Other Material*—Three females from a Passalid from Mt. Glorious, Queensland, 6th February, 1951 (coll. E. H. Derrick); two females and two males from a Passalid from Dalby, Queensland, 28th February, 1925 (coll. H. Geary).

*Description*—*Female holotype*—Of the same general facies and size as in *grossipes* Canest. Length of idiosoma  $1195\mu$ , width  $928\mu$ , ratio length to width =  $1.28:1.0$ .

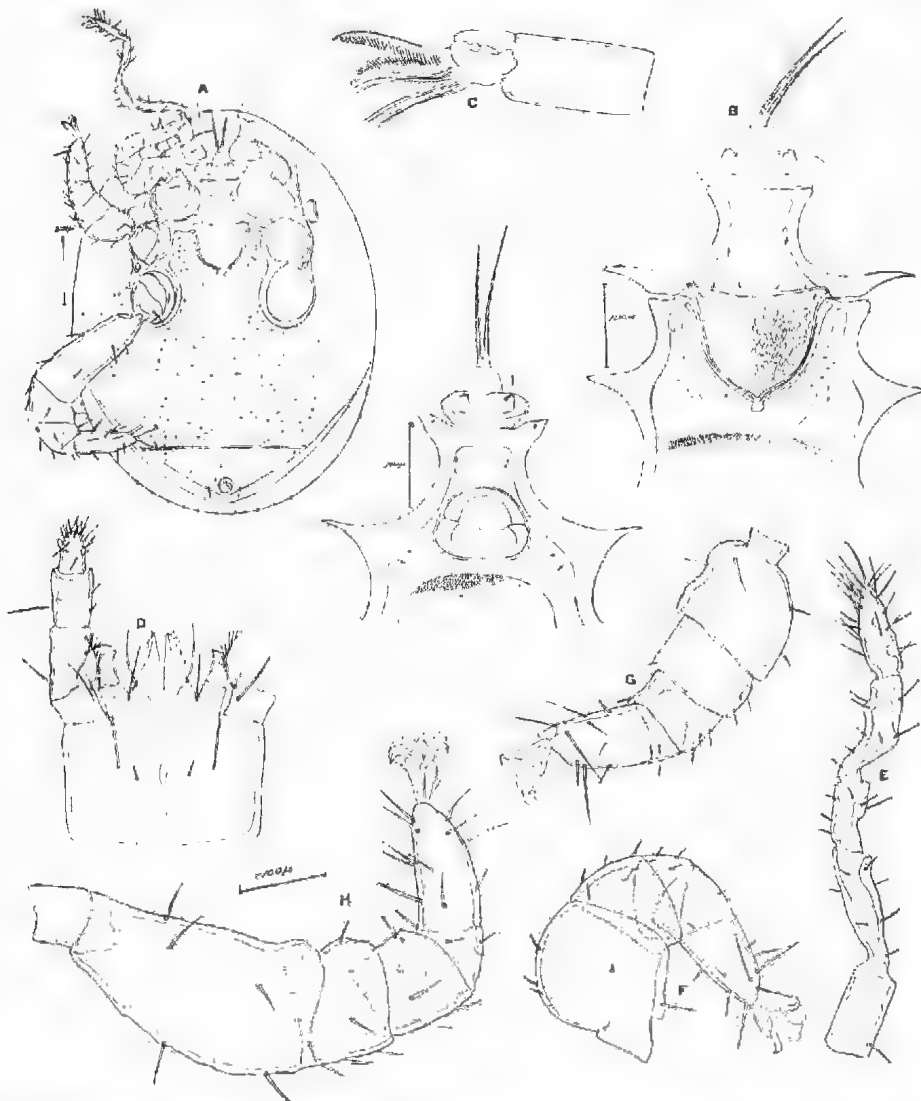


Fig. 2.—*Fedrizzia sellnicki* sp. nov., A-II Female; A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, chelicerae; D, gnathosoma and palp; E, leg I; F, leg II; G, leg III; H, leg IV; I, Male tritosternum, jugular and sternal shields.

*Dorsum*—Shield entire, covering the whole of the dorsum and underlapping venter as in other species.

*Venter*—Base of tritosternum slightly longer than wide; jugular shield as figured  $150\mu$  wide and  $47\mu$  long (deep) with rounded antero-lateral corners,

anterior margin straight except for a median depression, with one pair of setae ca.  $30\mu$  long curved backwards and  $61\mu$  apart and with one pair of lyriform pores  $75\mu$  apart and slightly nearer the posterior than the anterior margin; sternal shield with the anterior margin transverse and  $122\mu$  wide, sides contouring the edges of coxae II and continuing between coxae II and III to a maximum width of  $366\mu$  between the ends of the postero-lateral arms, narrowest part just behind anterior margin  $94\mu$ , posterior margin lightly convex medially for a width of  $169\mu$ , then curving posteriorly for a width of  $47\mu$  on each side before running obliquely forwards to the tips of the postero-lateral arms of the shield, shield with three pairs of minute setae and one pair of lyriform pores, the anterior pair of setae in line with the narrowest part in the mid-line of coxae II and  $65\mu$  apart, the other two pairs form a transverse row along the posterior margin with the median pair  $42\mu$  apart and  $35\mu$  from the laterals, the single pair of pores posterior of the anterior pair of setae; the sternogynial shield is bell-jar shaped with the anterior margin wider than the length,  $164\mu$  by  $117\mu$ , ratio width to length =  $1.4 : 1.0$ , with a pair of lyriform pores in the antero-lateral angles; latigynial shields slender and strap-like; mesogynial shield reduced; ventral shield as in the generic diagnosis, its posterior margin transverse and  $460\mu$  wide, with a few pores and at least one pair of setae apically; anal shield triangular  $450\mu$  wide by  $185\mu$  long, ratio width to length =  $2.43 : 1.0$ , with a few pores and minute setae posteriorly besides the pair of longer paranal setae.

*Gnathosoma* as in generic diagnosis.

*Legs*—Similar to *grossipes* Canest., I  $650\mu$  long, II  $545\mu$ , III  $508\mu$ , IV  $870\mu$  (femur long and gradually expanding to  $174\mu$  wide at apex).

*Male allotype* (from Imbil). Of the same general facies and size as in the female.

*Dorsum* as in the female.

*Venter*—Jugular shield smaller and narrower than in female  $103\mu$  by  $42\mu$  and fitting into the excavated anterior margin of the sternal shield, the single pair of recurved setae are on the anterior margin and  $51\mu$  apart, the single pair of pores are more posterior and  $56\mu$  apart; sterno-ventral shield as figured and as in the genus, anterior margin  $155\mu$ , narrowest between midline of coxae II  $103\mu$  and widest across the postero-lateral arms  $366\mu$ , anterior of the genital orifice it carries a pair of minute setae in the antero-lateral angles  $126\mu$  apart and another  $56\mu$  apart a little way in front of the orifice and about in line with the middle of coxae II, and a third pair in line with the posterior edge of the orifice and  $164\mu$  apart, a pair of pores lie about  $10\mu$  in front of the second pair of setae and the same width apart and a second pair of pores lie  $10\mu$  behind the third pair of setae and  $188\mu$  apart, the rest of the shield posterior of the genital orifice carries a number of fairly large pores and many minute setae, the genital orifice is large  $108\mu$  wide by  $85\mu$  long and is situated in a line between coxae II and III; the anal shield is triangular as in the female and of the same dimensions.

*Gnathosoma* and *Legs* as in female.

### *Fedrizzia carabi* sp. nov.

Text fig. 3 A-I

*Types*—Holotype female, one paratype female, allotype male and one paratype male from a Carabid beetle from under a log at Aiyura, New Guinea, at 5,000 ft., July, 1954 (Coll. H.W.).

*Description—Female holotype*—Of the same general facies of other species of the genus; rather small, length of idiosoma  $835\mu$ , width  $638\mu$ , ratio length to width =  $1.31:1.0$ .

*Dorsum*—Shield entire covering the whole body and under-lapping ventrally as in other species.

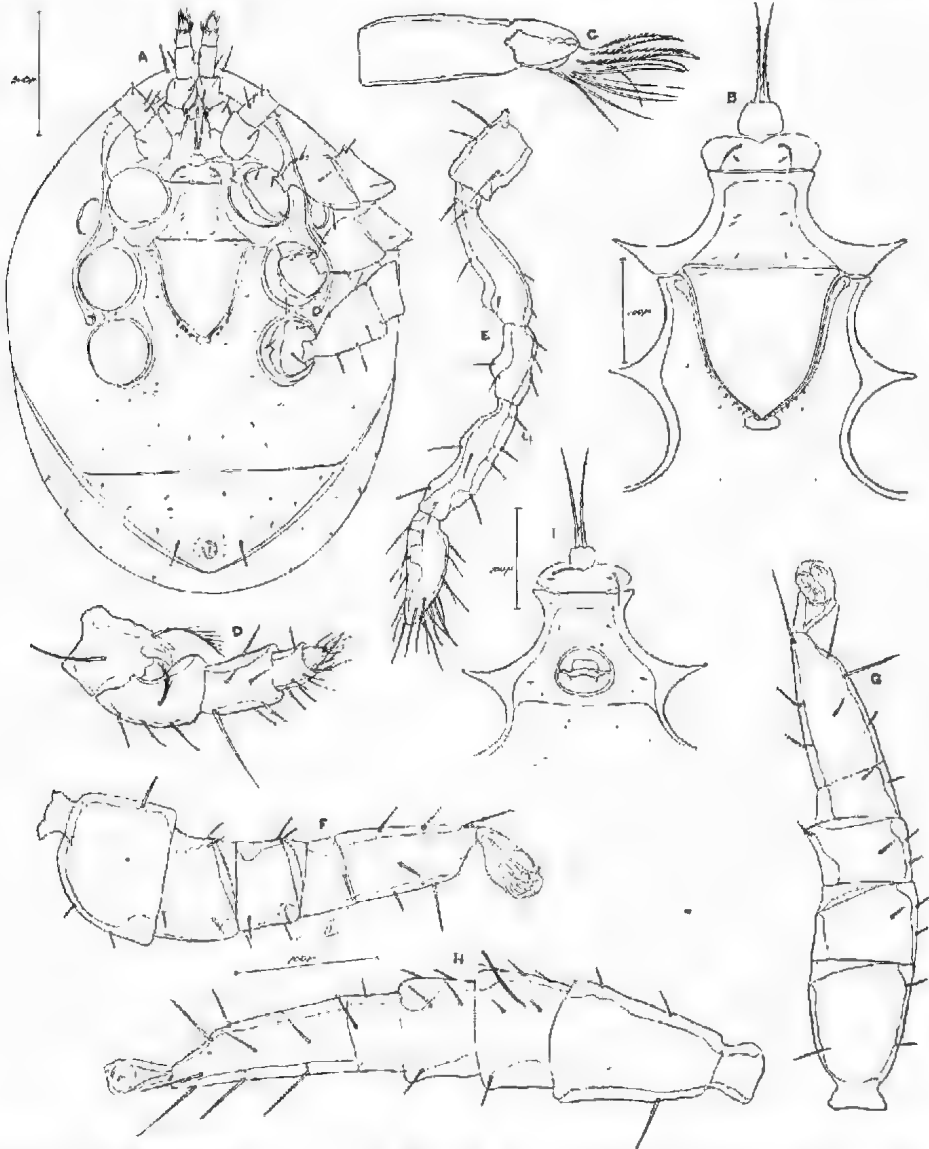


Fig. 3.—*Fedrizzia carabi* sp. nov. A-H Female: A, venter; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, mandible and chelicerae; D, palp; E, leg I; F, leg II; G, leg III; H, leg IV; I, Male, tritosternum, jugular and sternal shields.

*Venter*—Tritosternum with rather broad conical base and paired ciliated laciniae; jugular shields coalesced medially to form a single transverse crown-like shield,  $105\mu$  wide anteriorly but narrower posteriorly where it contours the anterior margin of the sternal shield,  $38\mu$  long, with one pair of curved fine

setae in anterior margin and  $52\mu$  apart, and one pair of lyriform pores more posterior; sternal shield coalesced with the endopodal shields of coxae II, anterior margin almost straight  $108\mu$  wide, sides curving inwards slightly in mid-line of coxae II to  $89\mu$  wide and then outwardly around coxae II to a width of  $282\mu$  between coxae II and III, length of shield  $103\mu$ , posterior margin straight for  $127\mu$  then with a posterior projection  $24\mu$  wide on each side and thereafter running obliquely forward to the apices of the postero-lateral arms between coxae II and III, with three pairs of setae and two pairs of pores, the anterior pair of setae in line with middle of coxae II, the others in a transverse row near the posterior margin, the inner pair  $52\mu$  apart, and  $19\mu$  from the laterals; sternogynial shield shaped like an inverted bell-jar with straight anterior margin  $141\mu$ , and  $141\mu$  long, ratio width to length =  $1.0 : 1.0$ , with one pair of pores in the antero-lateral angles; latigynial shields long and strap-like contouring the sides of the sternogynial shield and partly hidden under the inner edges of the anterior arms of the ventral shield; mesogynial shield very much reduced; ventral shield large, occupying most of the venter as in other species, the transverse posterior margin  $330\mu$  wide, externally of the peritreme between coxae II and III there is a duct or gland opening with the outer edge bow-shape and well sclerotised; the anal shield is triangular with transverse anterior margin  $330\mu$  wide, and the length  $150\mu$ , ratio width to length =  $2.2 : 1.0$ .

*Gnathosoma*, *chelicerae* and *palpi* as in other species.

*Legs*—I  $410\mu$  long, II-IV stout and thick but not strikingly so as in *grossipes*, II  $410\mu$  long, III  $376\mu$ , IV  $450\mu$ , with the femur  $89\mu$  across at apex.

*Male allotype*—Of the same general facies as the female; length of idiosoma  $835\mu$ , width  $638\mu$ .

*Dorsum* as in female.

*Venter*—Generally as in other species of the genus. Jugular shield separated from sternal as figured  $98\mu$  wide by  $24\mu$  long, with one pair of setae on anterior margin  $70\mu$  apart, and one pair of pores; sterno-ventral shield anteriorly slightly wider  $122\mu$  than the jugular shield with lightly concave anterior margin, it narrows to  $103\mu$  between coxae II and then expands to  $282\mu$  across the arms between coxae II and III; the genital orifice is fairly large  $70\mu$  wide by  $56\mu$  long, and lies between coxae II and III; the anal shield is large, triangular with anterior margin  $350\mu$  wide and its length  $150\mu$ .

*Legs*—As in the female, II-IV stout and thick, but IV not so markedly so as in *grossipes* and *sellnicki*.

*Remarks*—This species is one of the smaller of the genus so far known and can be separated as in the key to the species.

The specimens are in the collections of the South Australian Museum.

### *Fedrizzia derricki* sp. nov.

Text fig. 4 A-I

*Types*—The holotype female, allotype male and two paratype males from Atherton, Queensland. The holotype and allotype were collected from Passalids, April, 1945 (D. L. Collis) and the two paratype males from a *Megisthanus* sp. (Acarina), 28th March, 1945 (D. L. Collis).

*Description*—*Female holotype*—A medium sized species with the general facies of the genus. Length of idiosoma  $928\mu$ , width  $660\mu$ , ratio of length to width =  $1.4 : 1.0$ .

*Dorsum*—As in other species with the shield entire and under-lapping the venter; with few if any minute setae.



Venter—Tritosternum with rather broad basal piece and paired ciliated laciniae; jugular shields coalesced medially to form a single transverse shield  $117\mu$  wide by  $32\mu$  long, with the anterior margin medially excavate to fit the posterior margin of the tritosternum, posterior margin straight and shorter than

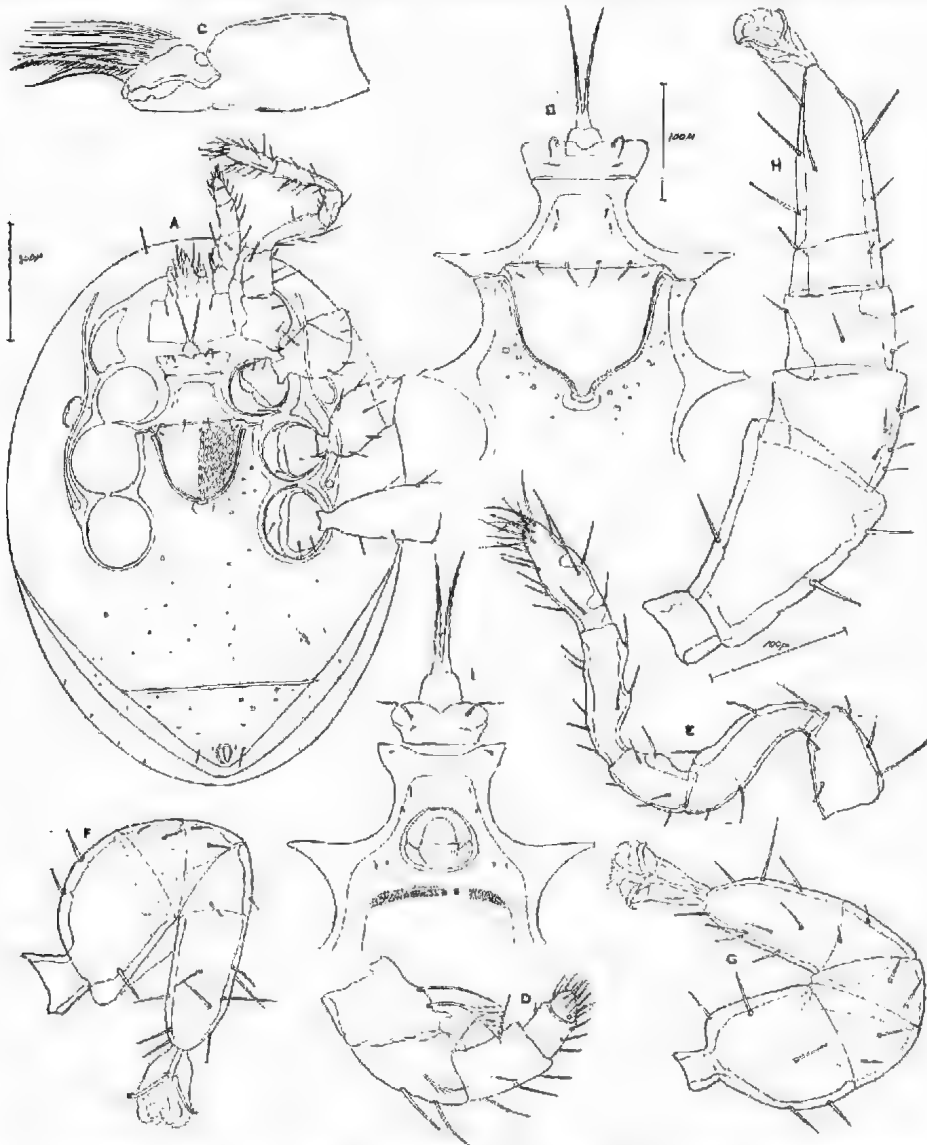


Fig. 4.—*Fedrizzia derricki* sp. nov. A–II Female: A, venter; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, mandible and chelicerae; D, palp; E, leg I; F, leg II; G, leg III; H, leg IV; I, Male, tritosternum, jugular and sternal shields.

anterior as figured, with a pair of setae  $50\mu$  apart on anterior margin, and a pair of lyriform pores; sternal shield coalesced with the endopodal shields of coxae II, anterior margin straight and  $90\mu$  wide, the lateral margins narrow between coxae II to  $82\mu$  and then curve around coxae II to a width across the postero-lateral arms between coxae II and III of  $258\mu$ , the length of the shield

is  $77\mu$ , the posterior margin is straight medially for about  $154\mu$ , when it is produced slightly posteriorly for a width of ca.  $36\mu$  on each side where it runs forward obliquely to the tips of the postero-lateral arms, it carries three pairs of setae and ? two pairs of pores (the anterior pair cannot be seen), the anterior setae (sternal setae II) are minute, the other two pairs longer and in a transverse row near the posterior margin, the medial pair  $27\mu$  apart and separated from the laterals by  $30\mu$ ; the sternogynial shield is broadly bell-shaped as figured,  $154\mu$  wide anteriorly and  $126\mu$  long, ratio of width to length =  $1.22 : 1.0$ , it is lightly reticulate and carries one pair of lyriiform pores in the antero-lateral angles; the latigynial shields are strap-like and contour the lateral margins of the sternogynial shield, being partially hidden under the inner margins of the anterior inter-coxal arms of the ventral shield; the mesogynial shield is very small as figured; ventral shield large, occupying most of the ventral surface, coalesced with other shields as in the genus, and with a straight transverse posterior border  $260\mu$ , with a number of pores; anal shield triangular  $260\mu$  wide anteriorly by  $127\mu$  long (deep), ratio width to length =  $2.04 : 1.0$ ; the peritremal shield is coalesced with the exopodal shields and only separated from outer extension of the ventral shield by a fine line, the stigmata lie between coxae III and IV and the peritreme runs forward to coxae I; on the outer extensions of the ventral shield, fairly close to the peritreme in region of coxae II is the atrium of a large gland of which the outer edge is well chitinated and lip-like.

*Gnathosoma* arising within the camerostome formed by the anterior underlap of the dorsal shield; hypostome, palpi and chelicerae as in other species.

*Legs*—As in other species, I  $520\mu$  long, antennaeform, angulate, with broad base, without caruncle or claws; II-IV thick and stout but not noticeably so as in *grossipes*, with short pretarsus, caruncle, and claws, II  $440\mu$ , III  $440\mu$ , IV  $356\mu$  long, I-IV 6-segmented.

*Male allotype*—General facies and size as in female.

*Dorsum* as in female.

*Venter*—Tritosternum as in female; jugular shield narrower than the anterior width of sternal,  $94\mu$  wide by  $37\mu$  long with the posterior border shorter than anterior, fitting into the evenly excavate anterior margin of sternal, with a pair of setae  $40\mu$  long and  $49\mu$  apart anteriorly and a pair of lyriiform pores posteriorly; anterior margin of sterno-ventral shield evenly concave  $117\mu$  wide, shield coalesced with endopodal and ventral shields, although a fine line running forward from coxae IV to almost coxae II and extending anteriorly to a short distance from the genital orifice indicates fusion of the ventral shield with the sternal cum endopodal shields of coxae II and III, the posterior margin of the ventral shield is straight, transverse and  $260\mu$  wide; the anal shield is  $260\mu$  wide by  $127\mu$  long; genital orifice between coxae II and III  $70\mu$  wide by  $61\mu$  long and  $47\mu$  from anterior margin.

*Gnathosoma* as in female.

*Legs* as in female.

*Remarks*—I am indebted to Dr. Sellnick for indicating the separation of this species from *grossipes* and the types are each represented in the South Australian collection by four slides of dissections made by him. The two paratype males are entire mounts. The species is dedicated to Dr. E. H. Derrick from whom I have received over the years much interesting material.

*Fedrizzia oudemansi* sp. nov.

Text fig. 5 A-I

*Types*—Holotype female and allotype male and a paratype of each sex from *Mastochilus dilatus* Dalm. from under a eucalyptus log at Glen Innes, New South

Wales (coll. G. F. Bornemissza, 9/10/56). One male from *Mastochilus dilatus* Dalm. from Washpool Crk. near Tenterfield, N.S.W., 8/10/56 (G.F.B.).

*Description*—*Female holotype*—A rather small species with the general facies as in other species of the genus. Length of idiosoma 777 $\mu$ , width 580 $\mu$ , ratio of length to width = 1.34:1.0.

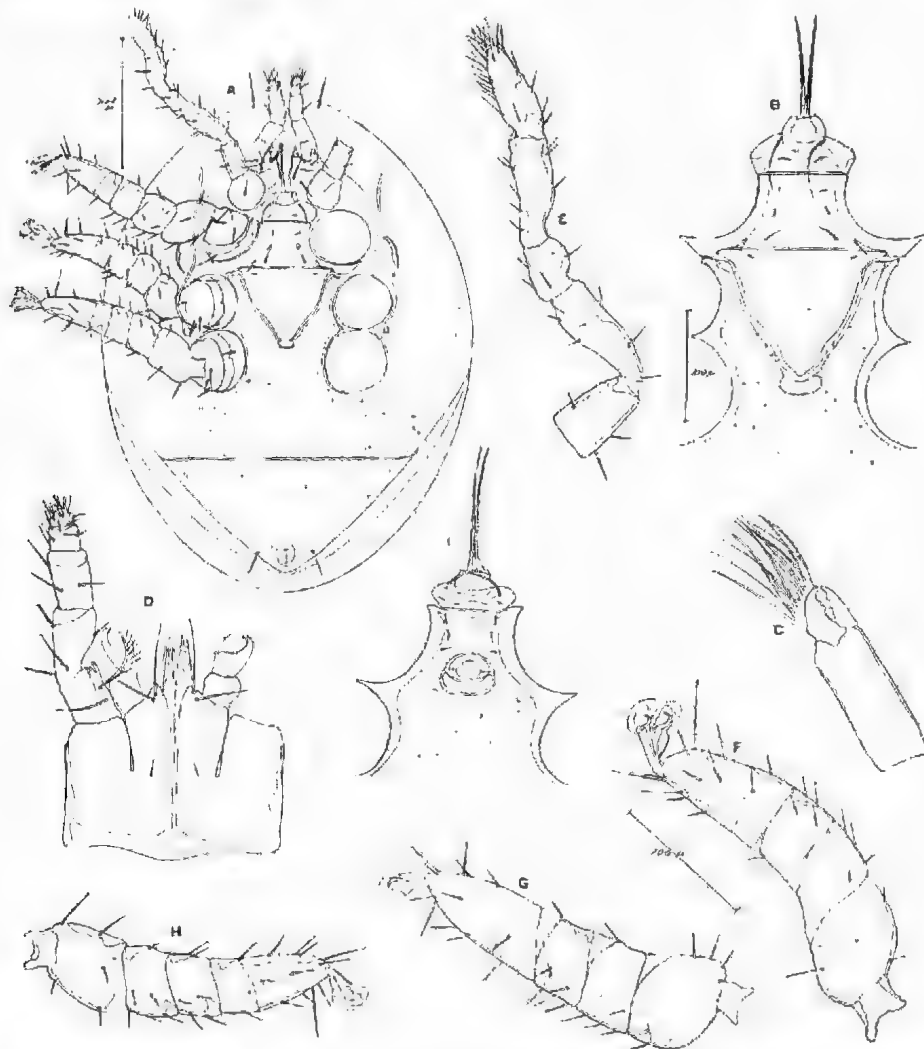


Fig. 5.—*Fedrizzia oulemansi* sp. nov. A-H Female: A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, mandible and chelicerae; D, gnathosoma and palp; E, leg I; F, leg II; G, leg III; H, leg IV; I, Male tritosternum, jugular and sternal shields.

*Dorsum*—Shield entire, covering the whole of the dorsum and under-lapping venter as in other species.

*Venter*—Base of tritosternum about as wide as long, with a pair of ciliated laciniac; jugular shield as figured, 94 $\mu$  wide by 32 $\mu$  long (deep), crown-shaped, anterior margin convex but with a median concavity for the base of the tritosternum, with one pair of long, 47 $\mu$ , curved setae in the anterior margin and

42 $\mu$  apart, with one pair of lyriform pores 37 $\mu$  apart; sternal shield with the anterior margin transverse and 84 $\mu$  wide, sides contouring the edges of coxae II and continuing between coxae II and III to a maximum width of 220 $\mu$  between the ends of the postero-lateral arms, narrowest just behind anterior margin to 75 $\mu$ , posterior margin straight medially for a length of 141 $\mu$  then extending posteriorly for 23 $\mu$  on each side before running obliquely and sharply forwards to the tips of the postero-lateral arms, shield with three pairs of setae and a pair of lyriform pores; the anterior pair of setae are minute in the antero-lateral angles and 45 $\mu$  apart, the second and third pairs of setae are longer to 19 $\mu$  and form a transverse posterior row with the medians 61 $\mu$  apart and 21 $\mu$  from the laterals, the pores are midway between the anterior and median posterior setae; sternogynial shield wider than long 150 $\mu$  by 117 $\mu$ , ratio of width to length = 1.28 : 1.0, with lightly convex but converging sides, anteriorly the margin is transverse forming outwardly produced angles with the lateral margins, the shield carries one pair of lyriform pores in the antero-lateral angles and 94 $\mu$  apart; latigynial shields slender and strap-like contouring the sternogynial shield and partly hidden under the inner edges of the ventral shield; mesogynial shield reduced; ventral shield as in the generic diagnosis, its posterior margin 400 $\mu$  wide and straight, with a few pores and minute setae; anal shield triangular with anterior margin 382 $\mu$  wide and the length 176 $\mu$ , with a pair of paranal setae 38 $\mu$  long and with a few pores and minute setae, ratio of width to length = 2.2 : 1.0.

*Gnathosoma* as in generic diagnosis.

*Legs*—Similar in general to other species of the genus; I 390 $\mu$  long, antennae form and somewhat angulate, II and III 348 $\mu$ , IV 370 $\mu$ , IV with femur not much longer than wide, but widening gradually to apex without any strong basal spine.

*Male allotype*—Of the same general facies as the female. Length of idiosoma 720 $\mu$ , width 534 $\mu$ .

*Dorsum* as in female.

*Venter*—Jugular shield smaller and narrower than in female, 70 $\mu$  wide by 25 $\mu$  long with a single pair of setae anteriorly 30 $\mu$  long and 52 $\mu$  apart, with one pair of lyriform pores 50 $\mu$  apart; sternal, genital-ventral shields coalesced to form the sterno-ventral shield as figured and as in the genus, anterior margin 88 $\mu$  wide, narrowing between coxae II to 74 $\mu$ , and widest across the postero-lateral arms between coxae II and coxae III to 206 $\mu$ , the anterior setae lie in the antero-lateral angles 50 $\mu$  apart, the second pair of setae lie just in front of the genital orifice and are 52 $\mu$  apart, the pores lie 14 $\mu$  in front of the second pair of setae, other setae and pores as far as can be seen as figured, the genital orifice lies between coxae II and III, it is 38 $\mu$  long by 47 $\mu$  wide; the anal shield is shaped as in the female with a transverse anterior margin 385 $\mu$ , and its length 174 $\mu$ , the pair of long paranal setae 33 $\mu$ .

*Gnathosoma* as in female.

*Legs*—As in female, I 352 $\mu$  long, II and III 325 $\mu$ , IV 348 $\mu$ .

#### *Fedrizzia bornemisszai* sp. nov.

Text fig. 6 A-1

*Types*—Holotype female, allotype male and paratype of each sex from *Mastochilus dilatus* Dalm. from under a eucalyptus lug at Hampton, Queensland, 8/11/56 (coll. G. F. Bornemissza).

*Description*—*Female holotype*—A fairly large species with the general facies as in other species of the genus. Length of idiosoma 928 $\mu$ , width 730 $\mu$ , ratio length to width = 1.27 : 1.0.

**Dorsum**—Shield entire covering the whole dorsum and under-lapping on to the venter, with many very fine short setae and pores, and with fine roughly transverse widely spaced lines, otherwise smooth.

**Venter**—Tritosternum with short base about as wide as long, and a pair of long ciliated laciniae; jugular shield wider than anterior width of sternal shield,

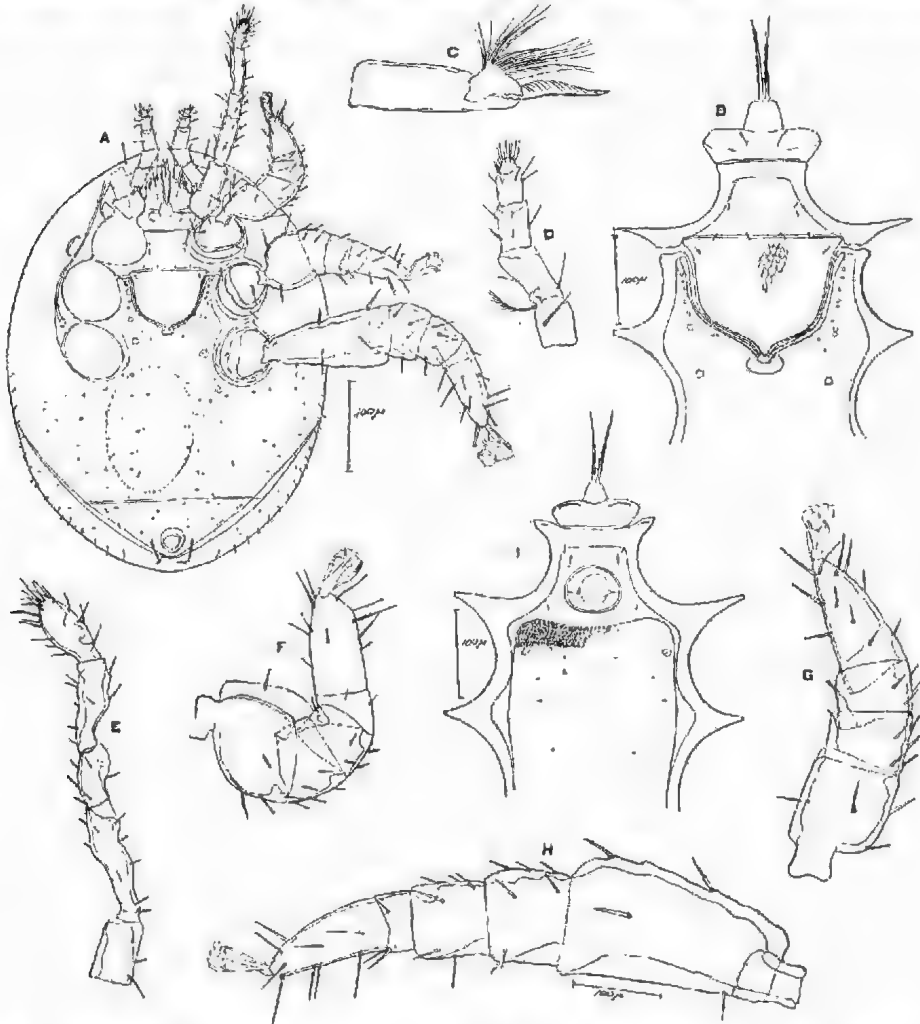


Fig. 6.—*Fedrizzia barnemisszai* sp. nov. A-H Female; A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, mandible and chelicerae; D, palp; E, leg I; F, leg II; G, leg III; H, leg IV; I, Male tritosternum, jugular and sternal shields.

somewhat crown-shaped, width  $130\mu$ , length (depth)  $38\mu$ , with one pair of setae behind the anterior margin  $55\mu$  apart and  $25\mu$  long, a pair of lyriform pores  $55\mu$  apart, posterior margin straight and  $110\mu$  wide; sternal shield as figured, anterior margin  $110\mu$  lightly concave for whole length, sides contouring coxae II with the shield narrowest in mid-line of coxae II to  $94\mu$ , and widest to  $242\mu$  between the points of the postero-lateral arms between coxae II and III, with three pairs of setae and one pair of pores, the anterior pair of setae

are minute and placed some distance,  $25\mu$ , back from the middle of the anterior margin and  $69\mu$  apart, the other two pairs of setae are also short and form a transverse row close to the posterior margin, of these the medians are  $50\mu$  apart and  $27\mu$  from the laterals, the pores are situated  $14\mu$  behind the anterior setae and a similar distance apart; the sternogynial shield as figured, wider than long,  $143\mu$  by  $116\mu$ , ratio width to length =  $1.23 : 1.0$ ; the surface is ornamented with a strong reticulation, the anterior margin is straight and the antero-lateral corners project shortly laterally, the sides are convex as figured, the pores are in the antero-lateral angles and  $130\mu$  apart; the latigynial shields are narrow and strap-like and contour the lateral margins of the sternogynial shield being partly hidden under the inner edge of the portions of the ventral shield lying between the coxae and the sternogynial shield; mesogynial shield small and reduced; ventral shield as in other species of the genus and with the surface ornamented with a fine grid of transverse lines cut by short longitudinal lines, its posterior margin aligns the anterior margin of the anal shield and is  $376\mu$  long, it is also furnished with a number of fairly large pores and some very minute setae; the anal shield is triangular,  $376\mu$  wide anteriorly and  $176\mu$  long, ratio width to length =  $2.21 : 1.0$ , with the surface, as in the ventral shield, the long paranal setae are  $25\mu$  long.

*Gnathosoma* as in the generic diagnosis.

*Legs*—Generally as in other species, I antennaeform and  $533\mu$  long, II-IV stout, II  $464\mu$ , III  $487\mu$ , IV  $730\mu$ , femur of leg IV truncheon-like,  $258\mu$  long and  $162\mu$  wide at apex.

*Male allotype*—Of the same general facies as the female. Length of idiosoma  $904\mu$ , width  $730\mu$ .

*Dorsum* as in female.

*Venter*—Jugular shield crown-shaped, smaller than in female,  $94\mu$  wide by  $33\mu$  long (deep), with the setae ca.  $23\mu$  long and  $33\mu$  apart, with one pair of lyridiform pores; sternal, genital and ventral shields coalesced to form the sterno-ventral shield as figured and as in the genus, anterior margin  $131\mu$ , the sides contouring coxae II-IV with the widest sternal portion between coxae II and III and  $305\mu$  between the postero-lateral arms; genital orifice large, situated between coxae II,  $61\mu$  wide by  $52\mu$  long; posterior margin aligned with anterior margin of anal shield and  $376\mu$  wide, surface of shield with some large pores, minute setae and with a fine grid or mesh of transverse striations with short longitudinal cross lines; anal shield triangular,  $376\mu$  wide and  $126\mu$  long as in female.

*Gnathosoma* as in other species.

*Legs* as in female, I  $520\mu$  long, II  $464\mu$ , III  $487\mu$ , IV  $696\mu$ .

*Remarks*—As in the key this species belongs to the *grossipes*, *sellnicki*, *derrieki* group in having the mesh or grid-like surface of the ventral shields in both sexes. The other two known species, *carabi* and *oudemansi*, have smooth non-ornamental ventral shields.

#### *Fedrizzia strandi* (Oudemans, 1927)

*Toxopeusia strandi* Ouds., 1927. Ent. Ber., 7 (156), p. 227: 1028, *Forma Buruana-Acacia* in Treubia, 7, Suppl. 2, pp. 60-66, figs. 69-81.

The genus *Toxopeusia* with *strandii* as type has generally been regarded by acaralogists as synonymous with *Fedrizzia* Canestrini with *grossipes* Canest. from Queensland as the type. That the two genera are synonymous is undoubted but from the specific features of the species of Fedrizzidae as brought out in the present study *strandii* would appear to be a validly different species from the Australian forms.



*Toxopeusia strandi* was very fully described and figured by Oudemans in 1928 from two females from "Station 12, Buru, 4-7 Feb., 1922; coll. L. J. Toxopeus"; the habitat was given with a query. A male specimen from "Wai Eno bis Wai Temun, 700-1000m., 3rd Nov., 1922" is described as the male of the same species.

For the female the only dimensions given are length of idiosoma  $857\mu$ , width  $630\mu$  (ratio of length to width =  $1.36:1.0$ ). Interpolating from his figures, however, the anal shield is  $408\mu$  wide by  $150\mu$  long, or a ratio of width to length of  $2.72:1.0$ ; the sternogynial shield is wider anteriorly than long, approximately  $163\mu$  by  $115\mu$ , or ratio width to length of  $1.42:1.0$ .

Thus in dimensions *strand*i is a broader species than *grossipes* with an anal shield three times as wide as long as compared with an anal shield only slightly more than twice as wide as long in *grossipes*. Other features shown in his description and figures of *strand*i in which this species differs from any of those found in Australia and New Guinea can be mentioned. Firstly he speaks of the pair of vertical setae as being wide apart and show them as being wider apart than in any other species. Behind these setae he describes and figures an eye-like organ on the dorsal surface; no such organ which is probably a pore has been observed in other species. On the ventral surface the pair of setae on the jugular shield (tetartosternum) are shown as in the antero-lateral angles, and not near to or flanking the base of the tritosternum. The tritosternum is stated to have no base, but the drawings, Figs. 70 and 75, show this as is usual in species of this genus, and over-lapped partially by the jugular shield.

On the above considerations as well as from geographical location, the females of *strand*i Ouds. must be regarded as a valid species, not synonymous with *grossipes* Canestrini, 1884.

Whether the male described by Oudemans as the same species is so, seems somewhat uncertain. His specimen was *much* smaller, idiosoma  $730\mu$  long by  $590\mu$  wide, or a ratio of  $1.237:1.0$ , than the females; the anal shield with a ratio of width to length of  $2.7:1.0$ . In the absence of definite hosts, and in the fact that the male and females were from different localities, the smaller size suggests a possibility that the male may not be conspecific with the female.

#### Key to the species of *Fedrizzia* Canest., 1884, s. str.

(largely based on females)

1. Larger species with length of idiosoma greater than  $1000\mu$  2  
     Smaller species, length of idiosoma less than  $1000\mu$ . 3
2. Sternogynial shield with the lightly convex sides gradually converging to the apex,  $169\mu$  wide anteriorly by  $141\mu$  long (ratio width to length =  $1.2:1.0$ ); anal shield  $400\mu$  wide by  $140\mu$  long (ratio width to length =  $2.86:1.0$ ); femur of leg IV 2.23 times as long as it is wide at apex. Length of idiosoma  $1160\mu$ , width  $870\mu$  (ratio length to width =  $1.33:1.0$ ). Ventral shield with mesh or grid.

*F. sp. cf. grossipes* Canest., 1884.

Sternogynial shield with sides medially almost straight and parallel before curving inwards to the apex, wider anteriorly than long  $164\mu$  by  $117\mu$  (ratio width to length =  $1.4:1.0$ ); anal shield  $450\mu$  wide by  $185\mu$  long (ratio width to length =  $2.43:1.0$ ); femur of leg IV 2.4 times as long as wide at apex. Length of idiosoma  $1195\mu$ , width  $928\mu$  (ratio length to width =  $1.28:1.0$ ). Ventral shield with mesh or grid.

*F. sellnicki* sp. nov.

3. Anal shield more than  $300\mu$  wide anteriorly. 4  
 Anal shield small,  $260\mu$  wide by  $127\mu$  long (ratio of width to length =  $2.04 : 1.0$ ); sternogynial shield of nearly uniform width for first half of its length, then sides curving in to apex,  $154\mu$  wide anteriorly and  $126\mu$  long (ratio width to length =  $1.22 : 1.0$ ); femur of leg IV twice as long as it is wide at apex. Length of idiosoma  $928\mu$ , width  $660\mu$  (ratio length to width =  $1.4 : 1.0$ ). Ventral shields with mesh or grid.  
*F. derricki* sp. nov.
4. Anal shield less than  $360\mu$  wide, with ratio of width to length less than  $2.5 : 1.0$ . 5  
 Anal shield greater than  $380\mu$  wide. 6
5. Ventral shields with fine mesh or grid. Anal shield  $324\mu$  wide by  $135\mu$  long, ratio width to length =  $2.4 : 1.0$ ; sternogynial shield wider anteriorly than long,  $160\mu$  by  $124\mu$ , ratio width to length =  $1.3 : 1.0$ ; femur of leg IV twice as long as wide at apex. Length of idiosoma  $918\mu$ , width  $612\mu$ , ratio of length to width =  $1.5 : 1.0$ .  
*F. grossipes* Canest., 1884.
- Ventral shields smooth, without mesh or grid. Anal shield  $330\mu$  wide and  $150\mu$  long, ratio of width to length =  $2.2 : 1.0$ ; sternogynial shield as wide anteriorly as it is long,  $141\mu$ ; femur of leg IV shorter and not so massive, only one fourth as long again as it is wide at apex. Length of idiosoma  $835\mu$ , width  $638\mu$ , ratio length to width =  $1.31 : 1.0$ .  
*F. carabi* sp. nov.
6. Ventral shields without grid or mesh. Anal shield  $382\mu$  wide by  $176\mu$  long, ratio width to length =  $2.2 : 1.0$ ; sternogynial shield wider anteriorly than long  $150\mu$  by  $117\mu$ , ratio width to length =  $1.28 : 1.0$ ; femur of leg IV not much thicker than III, about 1.3 times as long as wide at apex. Length of idiosoma  $777\mu$ , width  $580\mu$ , ratio length to width =  $1.34 : 1.0$ .  
*F. oudemansi* sp. nov.
- Ventral shields with mesh or grid. 7
7. A more broadly rounded species, length of idiosoma  $928\mu$ , width  $730\mu$ , ratio of length to width =  $1.27 : 1.0$ . Sternal setae II-IV very minute. Anal shield  $406\mu$  wide by  $139\mu$  long, ratio width to length =  $2.9 : 1.0$ ; sternogynial shield reticulate wider anteriorly than long,  $143\mu$  by  $116\mu$ , ratio width to length =  $1.23 : 1.0$ , sides almost parallel medially before curving to the apex; leg IV massive as in *grossipes*, femur more than twice as long as wide at apex.  
*F. bornemisszai* sp. nov.
- A less broadly rounded species, length of idiosoma  $857\mu$ , width  $630\mu$  ratio of length to width =  $1.36 : 1.0$ . Sternal setae longer. Anal shield  $408\mu$  wide by  $150\mu$  long, ratio of width to length =  $2.72 : 1.0$ ; sternogynial shield ? smooth, wider anteriorly than long ca.  $163\mu$  by  $115\mu$ , ratio  $1.42 : 1.0$ , with gradually converging sides; leg IV not so massive, femur ca. 1.6 times as long as wide at apex.  
*F. strandi* Ouds., 1927.

#### Genus NEOFFEDRIZZIA nov.

The species of this genus while having the general facies of the family differ from both other genera *Fedrizzia* Canestrini s. str. and *Parafedrizzia* gen.

nov. in that a free jugular shield is absent in the male. In that sex in front of the anterior margin of the sternal shield there is a pair of stout anteriorly directed processes of unknown function which overlie the bulbous base of the tritosternum. In both sexes the two long setae on the second segment of the palpi are only shortly ciliated or barbed. The femora of legs III and IV are short and wide with a prominent thick curved spine at the posterior corners in both males and females. The anal shield is present as in *Fedrizzia*. The body form may be somewhat rounded with curved sides or more elongate with the sides somewhat straighter.

Type *Neofedrizzia gayi* sp. nov.

*Neofedrizzia gayi* sp. nov.

Text fig. 7 A-K

*Types*—Holotype female, allotype male, two paratype females and one paratype male from a Passalid beetle in rotten log from Imbil, Queensland, 11th Sept., 1946 (F. J. Gay). Three females and five males also from a Passalid at Yurraman, Queensland, 29th Aug., 1935 (A.R.P.).

*Description*—*Holotype female*—A moderately large heavily chitlinised species with the general facies of *Fedrizzia* s. str., broadly oval with rounded sides. Length of idiosoma  $1210\mu$ , width  $850\mu$ .

*Dorsum*—Shield covering all the dorsum and under-lapping ventrally and anteriorly to form the anterior margin of the camerostome, marginally it is confluent with or coalesced with the outer edge of the large ventral shield as far back as the posterior edge of coxae IV then under-lapping the venter in a wide strip contouring and separated by a suture from the posterior part of the ventral and from the anal shield; dorsally a more hyaline sickle-shaped part is more or less demarcated by a line from the rest and overlaps the gnathosoma; this portion carries only the pair of vertical setae  $47\mu$  long and  $94\mu$  apart, but the rest of the dorsal shield is furnished with numerous pores but no perceptible setae.

*Venter*—Tritosternum as figured with an elongate basal part  $70\mu$  long and with paired ciliated laciniae to  $140\mu$  long; jugular shields coalesced medially to form a single crown-shaped shield  $146\mu$  wide and  $66\mu$  long (deep) with the posterior margin  $108\mu$  wide, with one pair of recurved setae on anterior margin flanking base of tritosternum  $38\mu$  apart and ca.  $23\mu$  long, with one pair of lyriiform pores subposteriorly; sternal shield coalesced with the endopodal shields of coxae II,  $108\mu$  wide anteriorly, narrowing to  $98\mu$  in midline of coxae II then contouring coxae II to a width of  $320\mu$  across the postero-lateral arms between coxae II and III, the shield is  $146\mu$  long (deep), the posterior margin is only lightly concave for its whole width of  $256\mu$  before running obliquely forwards to the tip of the arms, with three pairs of setae and ? one pair of pores, the anterior pair of setae (sternal setae II) are more or less in the antero-lateral angles and in front of the pores which are rather wider apart, the other two pairs of setae (sternal setae III and IV) lie in a transverse row near the posterior margin the medians being  $65\mu$  apart and  $19\mu$  from the laterals, all three pairs of setae are short, ca.  $11\mu$  long; sternogynial shield longer than wide,  $146\mu$  by  $126\mu$  anteriorly with lightly convex converging sides and rounded apex, with one pair of lyriiform pores near the antero-lateral corners, in line with the pores the shield is somewhat wider than the anterior margin; latigynial shields strap-like contouring the sides of the sternogynial and largely lying beneath the inner edges of the ventral shield (see Fig. 7 B and J); mesogynial shield reduced and covered by apex of sternogynial shield; ventral shield large occupy-

ing most of the ventral surface, marginally confluent or coalesced with the dorsal shield from the apex backwards to the region of coxae IV where it curves inwards to the antero-lateral corners of the anal shield and is contoured by that part of the under-lapping dorsal shield, between the antero-lateral corners of the anal shield it has a straight transverse margin separated by a suture from the transverse margin of the anal shield, antero-laterally it is coalesced with

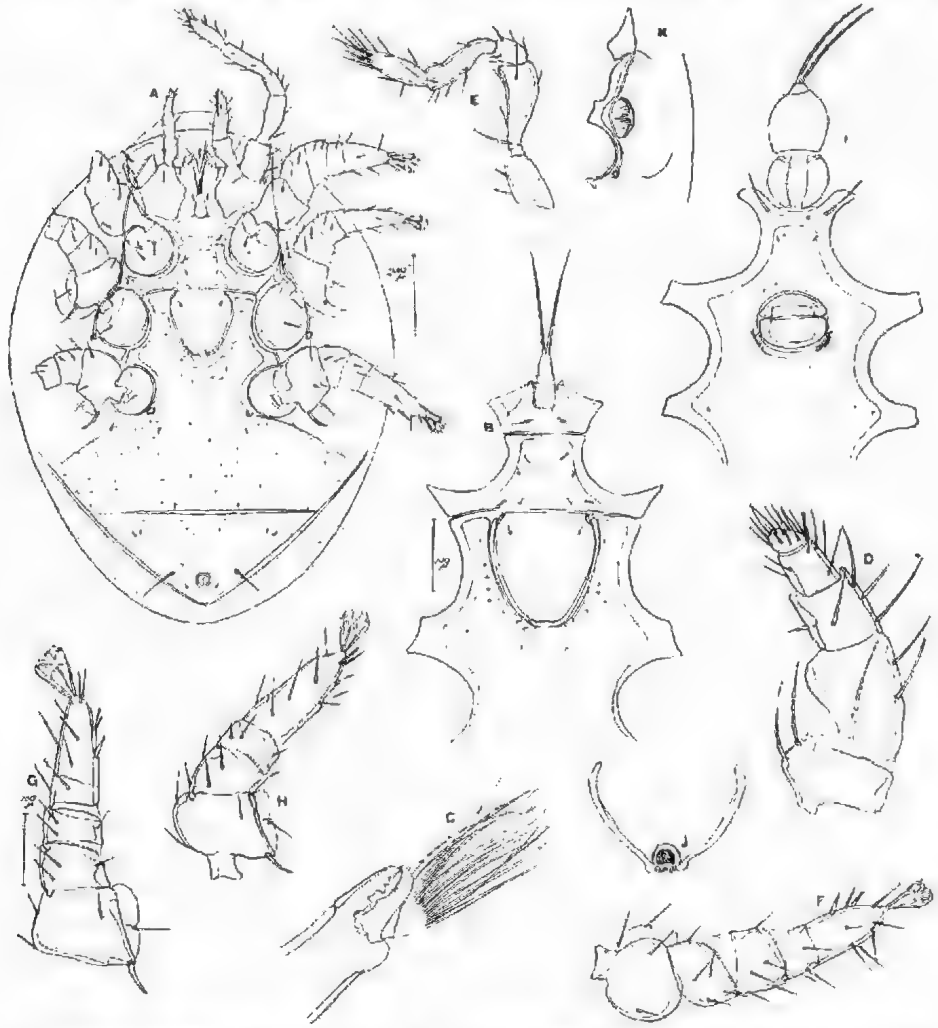


Fig. 7.—*Neofedrizzia gayi* g. et sp. nov. A-H, J-K, Female: A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, chelicerae; D, palp; E, leg I; F, leg II; G, leg III; H, leg IV; J, latigynial and mesogynial shields; K, atrium of duct between coxae II and III; I, Male tritosternum, pre-sternal appendages and sternal shield.

peritremal and exopodal shields of coxae II-IV, medially it extends forwards as two arms as far as posterior margin of the sternal shield and between the sternogynial shield and the coxae on each side, with the endopodal shields of which it is coalesced, the posterior margin is  $520\mu$  wide and it is furnished with numerous pores and a few minute inconspicuous setae; from the posterior edge of coxae IV a fine line runs obliquely backwards and outwards towards the

body edge which it does not reach, from coxae III another fine line runs backwards and then curves forwards but does not reach the body edge, in the out-side junction of coxae II and III is the atrium of a large duct the inner edges of which are strongly sclerotised; the peritremal shield is coalesced with the endopodal and ventral shields, with the stigmata lying between coxae III and IV and the peritreme running forward as figured to coxae I; the anal shield is large, triangular,  $520\mu$  wide on the transverse anterior margin and  $220\mu$  long (deep) with anus in the posterior angle, it carries many pores and a pair of long paranal setae  $70\mu$ .

*Gnathosoma*—Much as in species of *Fedrizzia*; chelicerae as figured, fixed digit with two strong and one smaller tooth, movable digit with a strong sub-basal tooth and subapically with minute denticles, with many hyaline processes two of which are blade-like and serrate, the others filamentous; palpi as figured, trochanter large and broad with an inner lobe anteriorly and two long barbed setae, specialised seta on tarsus two-tined; the mouth parts together with leg I arise within the camerostome, which in the lateral angles has a triangular sclerotised plate (the "axillar" plate of Sellnick *in lit.*).

*Legs*—All shorter than the body and 6-segmented, I slender and antennae-form, strongly angled, tarsus without caruncle or claws,  $552\mu$  long; II-IV shorter and stout, tarsi with caruncle and paired claws, II  $508\mu$  long, III  $508\mu$ , IV  $557\mu$ , the femora of II-IV are short and broad, with distinct hyaline lamellae, on III and IV the outer posterior angle of the femora carries a strong curved posteriorly directed spine characteristic of the genus.

*Allotype male*—Of the same size and general facies as in the female.

*Dorsum* as in female.

*Venter*—Tritosternum with a large bulbous basal part,  $84\mu$  long by  $84\mu$  wide, and a pair of ciliated laciniae  $140\mu$  long; no jugular shield; in front of the deeply concave anterior margin of the sternal shield and lying above the base of the tritosternum is a pair of free anteriorly directed processes curved inwardly to one another and apically bilobed, these processes of unknown function are  $94\mu$  long and  $33\mu$  wide as figured; the rest of the ventral shields except the anal are coalesced into a single shield the anterior sternal margin of which is  $150\mu$  wide and deeply concave, sternal setae I are long,  $70\mu$  and  $70\mu$  apart and lie in the antero-lateral angles, sternal setae II and III are minute, II  $33\mu$  from I and  $33\mu$  apart, III  $61\mu$  from II and close to the genital orifice and  $84\mu$  apart, between the bases of setae I are a pair of round pores  $33\mu$  apart and a second pair of pores (lyriform) lie slightly posterior of setae II and  $61\mu$  apart, while a third pair of pores also lyriform are about in line with setae III and  $145\mu$  apart; the genital orifice is between coxae II and III,  $94\mu$  wide by  $47\mu$  long, and around the posterior half on each side is a series of 8-9 pores; the anal shield is of the same shape and dimensions as in the female.

*Gnathosoma* and *Legs* as in female.

#### *Neofedrizzia canestrinii* sp. nov.

Text fig. 8 A-1

*Types*—Holotype female, allotype male, nine paratype females and four paratype males from a Passalid *Aulacocyclus edentulus* Mcl. from Hinchinbrook Island, N. Queensland, 9th Sept., 1956 (C. F. Bornemissza).

*Other material*—1 male from *A. edentulus* Mcl., Hampton, Queensland, 3rd October, 1956 (C.F.B.); 2 males from Tambourine, ? date (A. M. Lea); 1 male on Passalid, Atherton Tableland, Queensland, 28th March, 1945 (D. J. Collis); 1 male from *A. edentulus*, Wilson's Downfall near Tenterfield, New South Wales, 8th Oct., 1956 (C.F.B.).

*Description*—*Holotype female*—With the generic facies, but a rather small roundish species. Length of idiosoma  $812\mu$ , width  $638\mu$ .

*Dorsum*—Dorsal shield entire, covering the whole body and under-lapping venter as in other species; it is smooth except for some fine longitudinal striae circumferentially, and is furnished with many round small pores or the bases of minute setae.

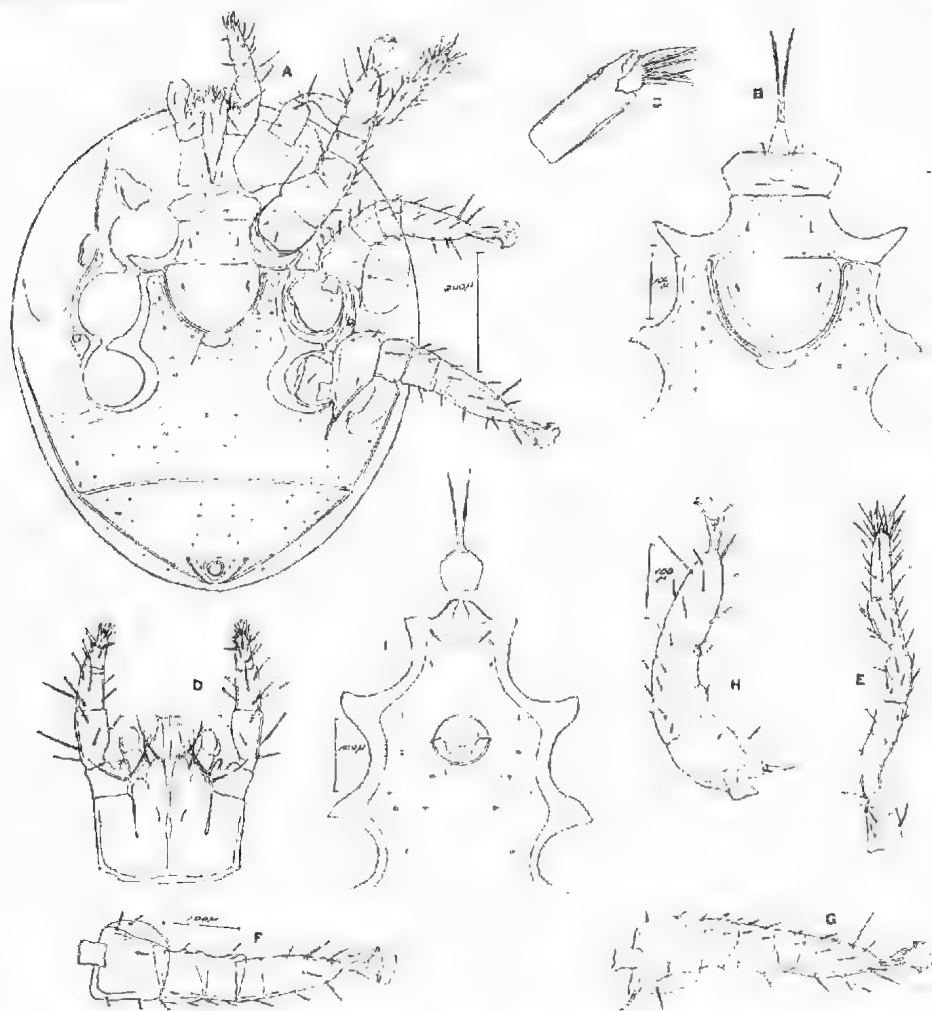


Fig. 8.—*Neofedrizzia canestrinii* sp. nov. A-H Female: A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, chelicerae; D, gnathosoma and palpi; E, leg I; F, leg II; G, leg III; H, leg IV; I, Male tritosternum, pre-sternal processes and sternal shield.

*Venter*—Tritosternum with elongate base  $47\mu$  long and  $25\mu$  wide, with paired ciliated laciniae to ca.  $110\mu$  long; jugular shield as figured, crown-shaped,  $132\mu$  wide by  $47\mu$  long (deep) and the posterior margin  $104\mu$  long, with one pair of recurved setae flanking the base of the tritosternum, ca.  $19\mu$  long and  $30\mu$  apart, with one pair of lyriiform pores  $11\mu$  in front of posterior margin and  $36\mu$  apart; sternal shield as figured,  $104\mu$  wide anteriorly, the sides only narrowing slightly from anterior angles, then coalescing with the endopodal shields of coxae II



contouring coxae II and then running between coxae II and III to a maximum width between apices of postero-lateral arms of  $282\mu$ , posterior margin straight medially for  $142\mu$ , then sloping slightly backwards for  $47\mu$  before running obliquely forwards to the tips of the postero-lateral arms, with three pairs of setae all very short, the first pair (sternal setae II)  $16\mu$  behind the anterior margin and  $44\mu$  apart, the second and third pairs of setae (sternal setae III and IV) in a transverse row near the posterior margin, the medians  $44\mu$  apart and  $33\mu$  from the laterals, with one pair of lyriform pores  $77\mu$  apart and  $16\mu$  behind sternal setae II, length (depth) of shield  $66\mu$ ; sternogynial shield as figured, wider anteriorly than it is long,  $124\mu$  by  $99\mu$ , ratio of length to width =  $1.0 : 1.25$ , with rounded sides, which expand slightly behind anterior corners to a width of  $137\mu$ ; latigynial shields strap-like, contouring sides of sternogynial and somewhat hidden under inner edges of ventral shield as in other species, mesogynial shield reduced and obscured by the inner anterior margin of the ventral shield and the bases of the latigynial shields; ventral shield large and covering most of the venter as in other species, its transverse posterior margin  $400\mu$ , with a number of round pores and minute setae as figured, the claviform processes are present beneath the shield but inconspicuous; anal shield large triangular,  $400\mu$  wide by  $91\mu$  long (deep), ratio width to length =  $4.4 : 1.0$ , with many round pores and a few minute setae besides the paranal setae of  $52\mu$  length; the peritremal shield and peritreme as in other species.

*Gnathosoma* as in the type and other species of the genus.

*Legs* all shorter than the body, I antennaeform,  $432\mu$  long, II and III  $400\mu$ , IV  $423\mu$ .

*Allotype male*—Facies, shape and dimensions as in the female.

*Dorsum* as in female.

*Venter*—Tritosternum with bulbous basal part,  $47\mu$  long and  $47\mu$  wide with subapical division, and paired ciliated laciniae ca.  $110\mu$  long; pre-sternal processes as figured, blunt and stoutly horn-shaped curved inwards, each  $27\mu$  long by  $16\mu$  thick medially; sterno-ventral shield as figured, anterior margin concave and  $99\mu$  wide, genital orifice wider than long  $60\mu$  by  $55\mu$ , and situated between coxae II and III, no pores marginally around the posterior half of the opening but there is a slight bulge on each side in the mid-line; anal shield of the same shape and dimensions as in the female.

*Gnathosoma* and *Legs* as in the female.

### *Neofedrizzia cynota* sp. nov.

Text fig. 9 A-I

*Types*—Holotype female, allotype male, one paratype female and two paratype males from *Mastochilus dilatus* Dalm. from Wilson's Downfall, near Tenterfield, New South Wales, 8th Oct., 1958 (C. F. Bornemissza). Also 2 males and 1 female from same host from Washpool Crk., near Tenterfield, 8/10/56 (C.F.B.).

*Description*—*Holotype female*—Only a moderately rounded species. Length of idiosoma  $893\mu$ , width  $638\mu$ , ratio of length to width =  $1.4 : 1.0$ .

*Dorsum*—Shield covering entire body and under-lapping venter as in other species, with many small rounded pores and minute setae, surface smooth.

*Venter*—Tritosternum with elongate basal part  $47\mu$  long by  $23\mu$  wide, and with paired ciliated laciniae to ca.  $120\mu$ ; jugular shield crown-shaped as figured,  $113\mu$  wide by  $49\mu$  long (deep), posterior margin  $82\mu$ , with a pair of recurved setae on anterior margin flanking base of tritosternum  $30\mu$  apart and  $33\mu$  long, with one pair of lyriform pores  $11\mu$  in front of posterior margin and  $35\mu$  apart; sternal shield as figured, anterior margin  $82\mu$ , sides narrowing slightly just behind



angles and then contouring coxae II to run between coxae II and III to a maximum width of the postero-lateral arms of  $247\mu$ , posterior margin straight medially for  $110\mu$  and then sloping backwards slightly for  $44\mu$  on each side before running obliquely forwards to the tips of the postero-lateral arms, with three pairs of setae and one pair of lyriform pores, the setae are all  $20\mu$  long, the anterior setae (sternal setae II) are  $19\mu$  behind the anterior margin and  $44\mu$  apart;

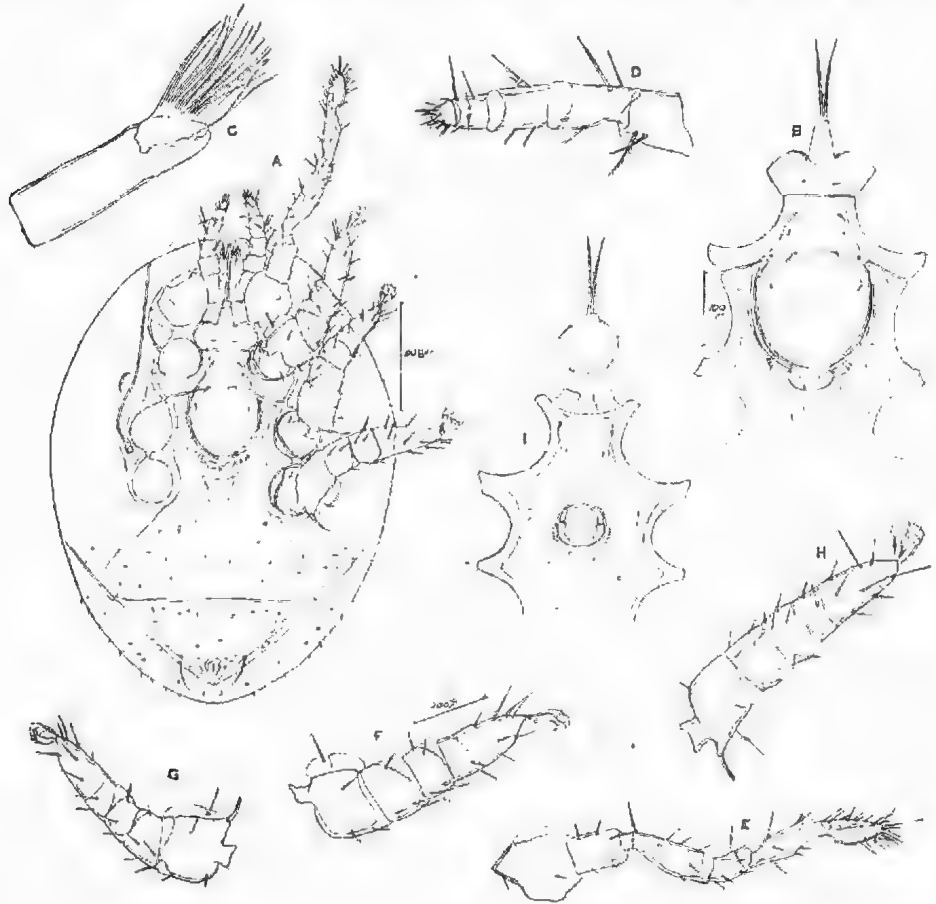


Fig. 9.—*Neofedrizzia cynota* sp. nov. A-H Female; A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, chelicerae; D, palp; E, leg I; F, leg II; G, leg III; H, leg IV; I, Male tritosternum, pre-sternal processes and sternal shield.

sternal setae III and IV form a transverse row near the posterior margin with the medians  $44\mu$  apart and  $25\mu$  from the laterals, the pores are  $60\mu$  apart and  $22\mu$  behind setae II; sternogynial shield as figured, only a little longer  $118\mu$  than wide anteriorly, its sides widen just in line with the pores to  $124\mu$  and then converge gradually in a rounded curve to the rounded apex, the pores are  $96\mu$  apart and lie  $28\mu$  behind the anterior margin; the latigynial shields are strap-like and contour the sides of the sternogynial shield as in other species; the mesogynial shield is reduced and obscured; the ventral shield is as in other species furnished with a number of round pores and a few minute setae, its transverse posterior margin is  $352\mu$  wide; the anal shield is triangular,  $352\mu$

wide by  $160\mu$  long (deep) giving a ratio of width to length of 2.2 : 1.0, the paranal setae are  $56\mu$  long.

*Gnathosoma* as in other species.

*Legs*—All shorter than body, I antennaeform,  $464\mu$  long, II-III  $353\mu$ , IV  $406\mu$ .

*Allotype male*—Of the same facies, size and dimensions as the female.

*Dorsum* as in female.

*Venter*—Tritosternum with a bulbous basal part,  $66\mu$  wide by  $66\mu$  long, and with paired ciliated laciniae ca.  $120\mu$  long; pre-sternal processes short and stumpy and apically truncate,  $23\mu$  long by  $23\mu$  wide, bent inwards; sterno-ventral shield as in other species, anterior margin concave and  $112\mu$  wide with blunt antero-lateral corners, genital orifice as figured lying between coxae III,  $55\mu$  long by  $55\mu$  wide, with a short series of pores around the posterior margin as figured, sternal setae I long  $30\mu$  and situated in the antero-lateral angles of the shield, anterior of these and behind bases of pre-sternal processes is a pair of small lyriform pores; anal shield of the same shape and dimensions as in the female.

*Gnathosoma* and *Legs*—As in female.

*Remarks*—Distinguished from other species as in the following key.

*Neofedrizzia camini* sp. nov.

Text fig. 10 A-K

*Types*—Holotype female, allotype male and one paratype of each sex from *Mastochilus dilatus* Dalm. from a rotten eucalypt log from Glen Innes, New South Wales, 9th Oct., 1956 (G. F. Bornemissza).

*Other material*—1 male, Upper Williams River, N.S.W., Oct., 1926 (A. M. Lea and E. W. Wilson); 1 male in ? moss and lichen, Waratah, Tasmania (no date); 1 male on a beetle, Mt. Clorious, Queensland, 6th Feb., 1951 (E. H. Derrick).

*Description*—*Holotype female*—A rather oval elongate species, of the generic facies. Length of idiosoma  $1160\mu$ , width  $770\mu$ , ratio length to width = 1.5 : 1.0.

*Dorsum*—Dorsal shield entire, covering the whole body and under-lapping venter as on other species. Surface smooth with numerous small pores and some minute setae.

*Venter*—Tritosternum with elongate basal part  $66\mu$  long by  $33\mu$  wide and a pair of ciliated laciniae ca.  $120\mu$  long; jugular shield crown-shaped as figured,  $150\mu$  wide by  $66\mu$  deep, posterior margin  $112\mu$  wide, with a pair of fine recurved setae flanking base of tritosternum  $55\mu$  long and their bases  $30\mu$  apart, with one pair of lyriform pores  $47\mu$  apart and  $16\mu$  in front of posterior margin; sternal shield as figured, anterior margin  $112\mu$ , sides contouring coxae II and running between coxae II and III to form the postero-lateral arms with a width of  $305\mu$ , the posterior margin  $258\mu$  is straight medially for  $144\mu$  and laterally slopes slightly backwards for  $57\mu$  on each side before running obliquely forwards to the tips of the postero-lateral arms, with three pairs of setae and one pair of lyriform pores, the setae are all fine and ca.  $27\mu$  long, the first pair (sternal setae II) lie in the antero-lateral angles  $22\mu$  behind the anterior margin and  $47\mu$  apart, the others form a transverse row near the posterior margins with the medians  $60\mu$  apart and  $30\mu$  from the laterals, the pores are  $91\mu$  apart and  $30\mu$  behind setae II; sternogynial shield as figured, slightly longer than wide on anterior margin  $144\mu$  by  $132\mu$ , the sides expand to a width of  $151\mu$  in line with the pores and then curve more or less evenly to form a rounded shape, the pores lie  $41\mu$  behind the anterior margin and  $110\mu$  apart; latigynial shields narrow and strap-like contouring the sternogynial shield as in other species; the meso-

gynial shield is reduced and obscured; the ventral shield is large and coalesced with other shields as in other species, its transverse posterior margin is  $510\mu$  wide, the surface shows many small pores and some fine minute setae; the anal shield is large and triangular,  $510\mu$  wide by  $244\mu$  long (deep), giving a ratio of width to length of  $2.09:1.0$ , the paranal setae are  $40\mu$  long.

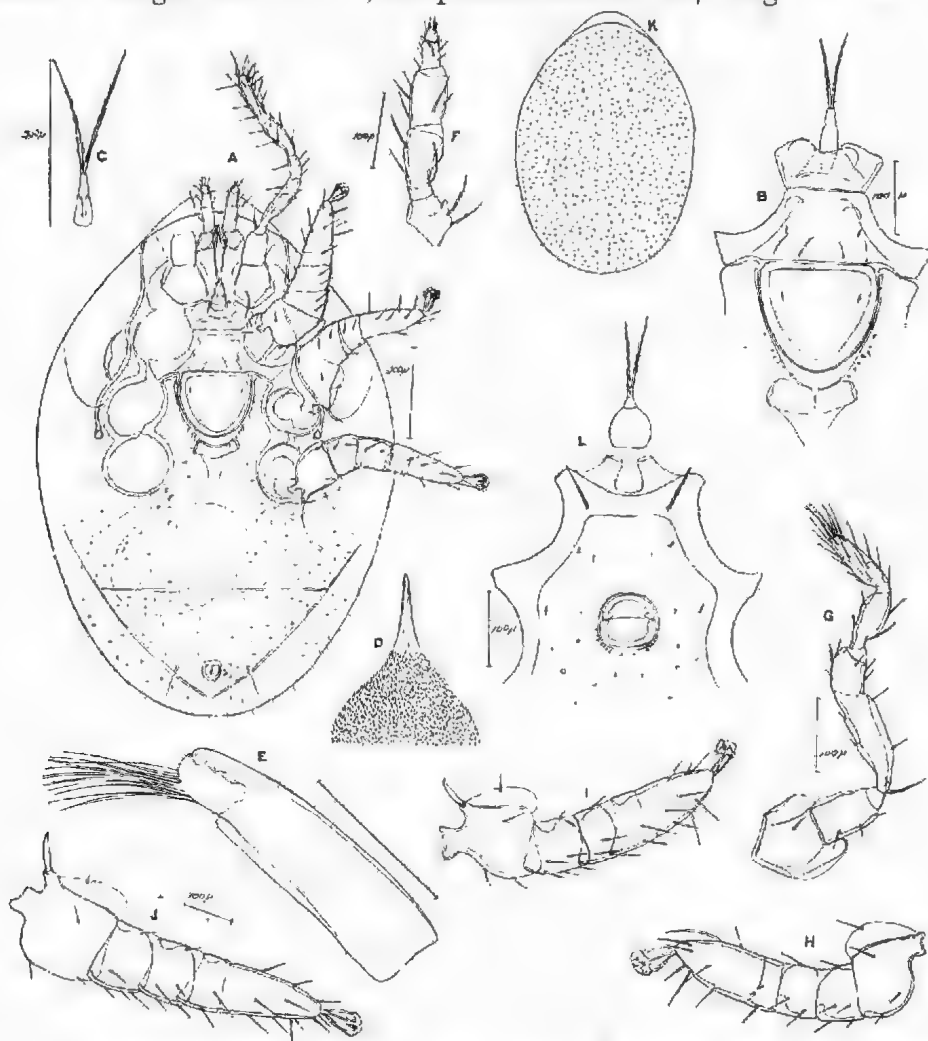


Fig. 10.—*Neofedrizzia camini* sp. nov. A-K, Female; A, ventral view; B, tritosternum, jugular, sternal, sternogynial, lateral shields and claviform processes enlarged; C, tritosternum; D, tectum; E, mandible and chelicerae; F, palp; G, leg I; H, leg II; I, leg III; J, leg IV; K, dorsal shield; L, Male tritosternum, pre-sternal processes and sternal shield.

*Gnathosoma*—As in other species.

*Legs*—All shorter than body, I antennaeform  $590\mu$  long, II and III  $464\mu$ , IV  $520\mu$ .

*Allotype male*—Of the same shape and dimensions as in the female.

*Dorsum*—As in female.

*Venter*—Tritosternum with bulbous basal part  $70\mu$  long by  $70\mu$  wide, and a pair of ciliated laciniae ca.  $120\mu$  long; pre-sternal processes short and stumpy

curved inwards and with truncate apices,  $42\mu$  long by  $25\mu$  wide; sterno-ventral shield as in other species, anterior margin concave  $140\mu$  wide with blunt truncate antero-lateral corners, genital orifice lying between coxae III as figured  $86\mu$  long by  $66\mu$  wide with a series of seven or eight pores around the posterior half, sternal setae I  $38\mu$  long and situated in the antero-lateral angles of the shield, other pores and small setae are present, some of which probably represent sternal setae II-IV and their respective pores; anal shield of the same shape and dimensions as in the female.

*Gnathosoma* and *Legs*—As in the female.

*Remarks*—Distinguished from other species as in the following key. The species is named after Dr. J. H. Camin who has contributed much to the study of the comparative morphology of the Mesostigmata.

*Neofedrizzia goriossiae* sp. nov.

Text fig. 11 A-L

*Types*—Holotype female, allotype male and seven paratype females from *Mastochilus dilatus* Dalm. from rotting eucalypt log. Hampton, Queensland, 8th November, 1956 (C. F. Bornemissza).

*Description*—*Holotype female*—A moderately large oval species widest in line of coxae III and then tapering somewhat before becoming rounded posteriorly from line of anterior margin of anal shield. Length of idiosoma  $1020\mu$ , width  $696\mu$ ; giving a ratio of length to width of 1.46:1.0.

*Dorsum*—Dorsal shield covering all the body and under-lapping venter as in other species, with many small round pores, and some minute setae.

*Venter*—Tritosternum with elongate basal part,  $52\mu$  long by  $28\mu$  wide, with a pair of ciliated laciniae to  $140\mu$  long; jugular shield crown-shaped as figured  $132\mu$  wide by  $47\mu$  long (deep), posterior margin  $99\mu$ , with a pair of anterior recurved setae ca.  $37\mu$  long flanking the base of the tritosternum and their bases  $30\mu$  apart, and  $10\mu$  in front of posterior margin; sternal shield as figured, anterior margin  $99\mu$  wide, sides contouring coxae III and running between coxae II and III to form the antero-lateral corners of the postero-lateral arms with a maximum width of  $275\mu$ , the posterior margin is straight medially for a width of  $124\mu$  then bends lightly backwards for  $50\mu$  on each side before running obliquely forwards to join the tips of the postero-lateral arms, with three pairs of setae and one pair of lyriform pores, the anterior pair of setae (sternal setae II) are ca.  $25\mu$  long,  $55\mu$  apart and lie  $20\mu$  behind the anterior margin, the other two pairs of setae (sternal setae III and IV) form a posterior transverse row with the medians  $47\mu$  apart and  $23\mu$  from the laterals, these setae are also ca.  $25\mu$  long, the pores are  $70\mu$  apart and  $23\mu$  behind sternal setae II; sternogynial shield as figured, anterior margin  $108\mu$ , length  $131\mu$ , the sides expand slightly to a width of  $131\mu$  in line of the pores to curve and converge to a broadly rounded apex, with one pair of lyriform pores  $103\mu$  apart and  $33\mu$  behind anterior margin; latigynial shields strap-like and contouring sides of sternogynial shields as in other species; mesogynial shield reduced and obscured; ventral shield large, occupying most of the venter and coalesced with all other shields except the anal, its posterior margin is transverse,  $404\mu$  wide and separated from the anal by a suture, it carries a number of pores and a few minute setae; anal shield large, triangular,  $404\mu$  wide anteriorly and  $202\mu$  long (deep) giving a ratio of width to length of 2.0:1.0, it is furnished with a number of pores and some fine minute setae, as well as a pair of paranal setae  $56\mu$  long.

*Gnathosoma*—As in other species.

*Legs*—All shorter than body, I antennaeform,  $522\mu$  long, II and III  $430\mu$ , IV  $464\mu$ .

*Allotype male*—Of the same shape and dimensions as in the female.

*Dorsum*—As in the female.

*Venter*—Tritosternum with bulbous base  $85\mu$  wide and  $70\mu$  long, with a pair of ciliated laciniae  $140\mu$  long; pre-sternal processes as figured, curved in-

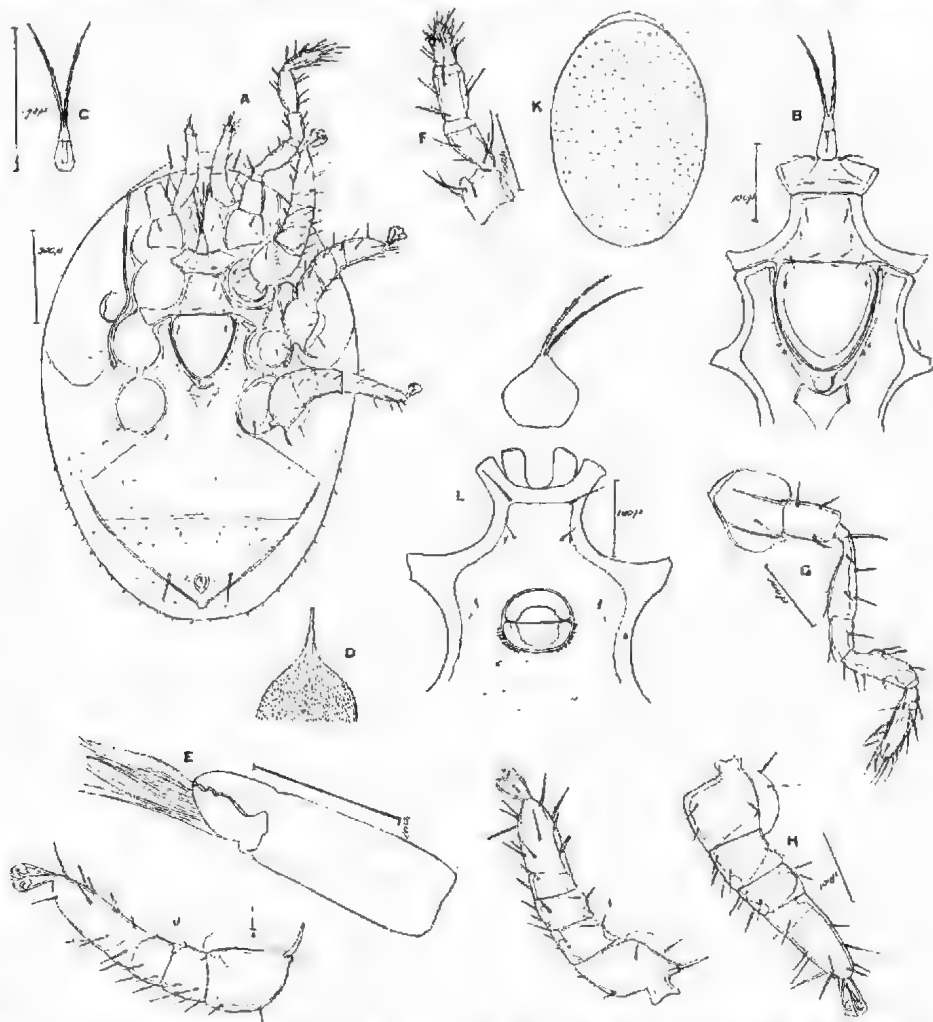


Fig. 11.—*Neofedrizzia gorirossiae* sp. nov. A-K, Female: A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, tritosternum; D, tectum; E, mandible and chelicerae; F, palp; G, leg I; H, leg II; I, leg III; J, leg IV; K, dorsal shield; L, Male tritosternum, pre-sternal processes and sternal shield.

wards,  $47\mu$  long by  $23\mu$  wide and with parallel sides and truncate apex; sterno-ventral shield as in other species, anterior margin  $136\mu$  wide, deeply and widely excavated for the pre-sternal processes and base of tritosternum, sternal setae I in antero-lateral angles and  $47\mu$  long, antero-lateral angles of shield blunt, sternal setae II also moderately long ca.  $23\mu$  and  $52\mu$  apart and  $33\mu$  behind setae I in line with a pair of small lyriiform pores  $70\mu$  apart,  $70\mu$  behind these is a pair of

larger lyriform pores  $132\mu$  apart, otherwise a few round pores and several minute setae, the genital orifice is  $70\mu$  wide by  $66\mu$  long and lies mainly between coxae III, the posterior half is margined by a series of about ten pores on each side; the anal shield is as in the female.

*Gnathosoma and Legs*—As in the female.

*Remarks*—This species can be separated as in the key.

It is named in honour of Dr. Flora Gorirossi, joint author with Dr. Camin of their valuable contributions on the comparative morphology of the Mesostigmata.

*Neofedrizzia tragardhi* sp. nov.

Text fig. 12 A-K

*Types*—Holotype female, allotype male, nine paratype females and five paratype males from *Mastochilus dilatus* Dalm. from a eucalyptus log, at Washpool Creek, near Tenterfield, New South Wales, 8th Oct., 1956 (G. F. Bornemissza).

*Description*—*Holotype female*—A large elongate oval species widest anteriorly of the middle and in line with coxae III. Length of idiosoma  $1369\mu$ , greatest width  $905\mu$ , width across anterior margin of anal shield  $754\mu$ , ratio of length to width =  $1.51:1.0$ .

*Dorsum*—Shield covering entire body and under-lapping on to venter as in other species, furnished with numerous small round pores and some obscure minute setae, on the hyaline anterior portion with a pair of vertical setae  $47\mu$  long and  $94\mu$  apart.

*Venter*—Tritosternum with elongate basal part  $56\mu$  long by  $32\mu$  wide, and a pair of ciliated laciniae ca.  $160\mu$  long; jugular shield as figured, crown-shaped,  $164\mu$  wide by  $56\mu$  long (deep) and the posterior margin  $127\mu$ , with a pair of very long  $90\mu$  setae anteriorly and flanking base of tritosternum with their bases  $38\mu$  apart, with a pair of lyriform pores  $10\mu$  in front of posterior margin and  $52\mu$  apart; sternal shield as figured, anterior margin straight,  $127\mu$  wide, sides at first slightly narrowing then contouring coxae II to extend between coxae II and III to form the postero-lateral arms with a width of  $348\mu$ , posterior margin straight medially for  $170\mu$  then sloping backwards for  $60\mu$  on each side before running obliquely forwards to the tips of the postero-lateral arms, with three pairs of setae and one pair of lyriform pores, the first pair of setae (sternal setae II) are very long and slender,  $23\mu$  behind anterior margin,  $80\mu$  long and  $70\mu$  apart; the other two pairs (sternal setae III and IV) form a transverse row near the posterior margin, they are only about half the length of setae II  $33\mu$  with the medians  $75\mu$  apart and  $23\mu$  from the laterals, the pores are  $33\mu$  behind setae II and  $99\mu$  apart; sternogynial shield as figured, anterior margin transverse and  $141\mu$  wide, the sides expand to a width of  $152\mu$  in line of the lyriform pores, then curve and converge to the rounded apex, the length of the shield is  $146\mu$ , the one pair of pores is  $38\mu$  behind the anterior margin and  $113\mu$  apart; the latigynial shields are strap-like and contour the sternogynial shield as in other species; the mesogynial shield is reduced and obscured; the ventral shield is large, coalesce with the other shields except the anal and occupies most of the venter, its posterior margin is transverse and  $615\mu$  wide, it is furnished with many small round pores and a few minute setae; the anal shield is large, with the anterior margin  $615\mu$  wide and its length (depth)  $302\mu$ , giving a ratio of length to depth of  $2.04:1.0$ ; the paranal setae are  $85\mu$  long.

*Gnathosoma* as in the other species.

*Legs*—All shorter than body, I antennaeform,  $638\mu$  long, II and III  $550\mu$ , IV  $626\mu$ .

*Allotype male*—Similar in shape and size to the female.

*Dorsum* as in female.

*Venter*—Tritosternum with bulbous base  $70\mu$  wide by  $61\mu$  long, and paired ciliated laciniae  $160\mu$  long; pre-sternal appendages short and stumpy,  $33\mu$  long by  $19\mu$  wide with truncate apex and turning inwards towards one another; sterno-ventral shield as in other species; anterior margin deeply concave and  $160\mu$  wide, sternal setae I strong in the blunt antero-lateral angles and  $42\mu$  long,  $56\mu$  behind

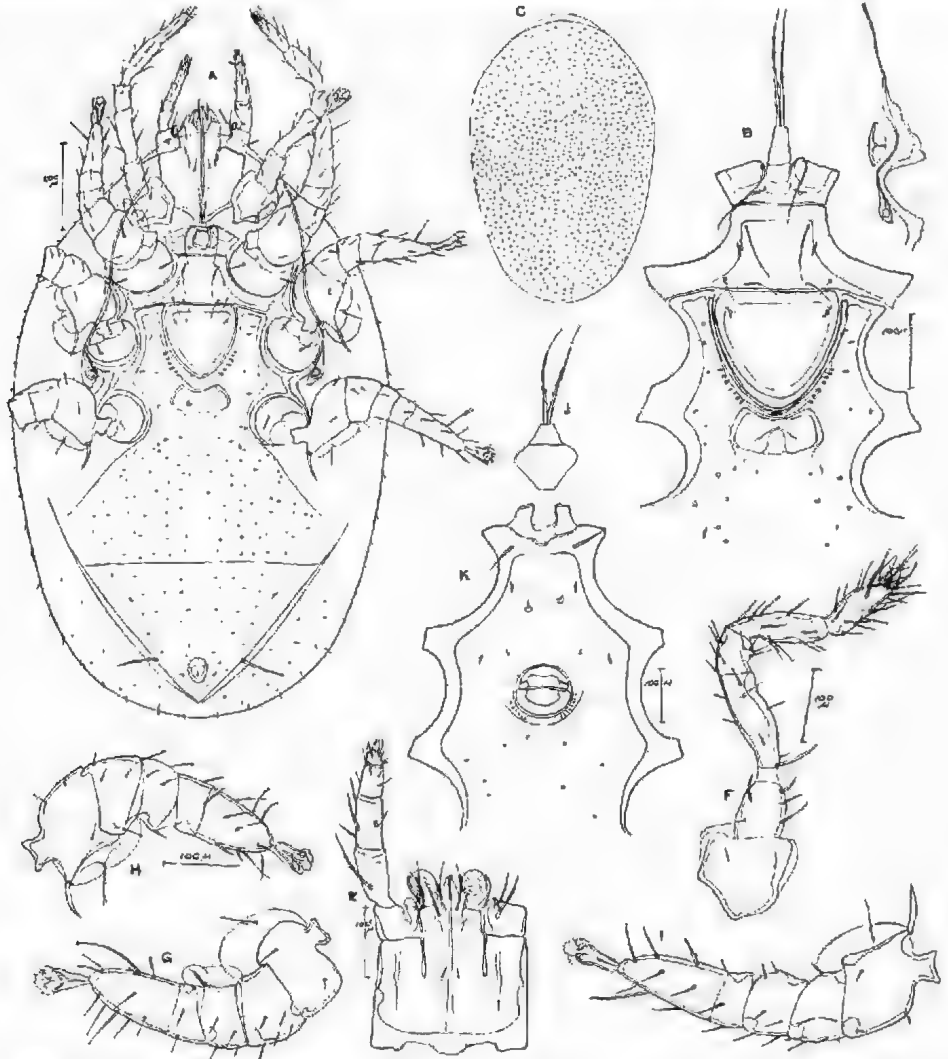


Fig. 12.—*Neofedrizzia tragardhi* sp. nov. A-I, Female: A, ventral view; B, tritosternum, jugular, sternal, sternogynial and lateral shields and claviform processes enlarged; C, dorsal shield; D, atrium of duct between coxae II and III; E, gnathosoma and palp; F, leg I; G, leg II; H, leg III; I, leg IV; J-K, Male: J, tritosternum; K, pre-sternal processes and sternal shield.

these and  $85\mu$  apart is a pair of small lyriform pores, while  $94\mu$  behind these and  $164\mu$  apart is a pair of larger lyriform pores, there are also other indistinct pores and minute setae, the genital orifice is  $70\mu$  long by  $66\mu$  wide and lies be-



tween coxae III, its basal half has a series of about eight pores on each side; the anal shield is as in the female.

*Remarks*—Other specimens are 10 females and 3 males from *Mastochilus dilatus* Dalm. from Wilson's Downfall, New South Wales, 8th Oct., 1956 (G. F. Bornemissza); 3 female and 4 males on a Passalid in rain forest at Eubenangee, near Innisfail, Queensland, 11th Dec., 1945 (J. C. Brooks).

This species is remarkable for the long jugular and sternal setae and can be separated as in the key. It is dedicated to the noted Acarologist, the late Prof. I. Trägårdh, who laid the bases for the modern study of the comparative morphology of the Mesostigmata.

### *Neofedrizzia vidua* sp. nov.

Text fig. 13 A-K

*Types*—Holotype female, allotype male, one paratype female and three paratype males from a beetle from Mt. Glorious, Queensland, 6th February, 1957 (E. H. Derrick).

*Description*—*Holotype female*—A large and almost round species of the general facies of the genus. Length of idiosoma  $1392\mu$ , width  $1020\mu$ , giving a ratio of length to width of  $1.36:1.0$ .

*Dorsum*—As in other species with the shield covering the whole dorsum and under-lapping ventrally as in other species, with numerous small round pores and perhaps a few minute setae, laterally running backwards and outwards beneath the cuticle can be seen in this (and in some of the other species) an irregular series of larger round discs which might be pores but do not open to the surface.

*Venter*—Tritosternum with elongate basal part,  $70\mu$  long by  $33\mu$  wide, with a pair of ciliated laciniae  $150\mu$  long; jugular shield crown-shaped,  $174\mu$  wide by  $70\mu$  long (deep) and  $131\mu$  wide on the posterior margin, with a pair of short recurved setae  $32\mu$  long flanking the tritostomal base on the anterior margin, with one pair of lyriform pores  $19\mu$  in front of posterior margin and  $52\mu$  apart; sternal shield as figured, anterior margin  $131\mu$  wide, length of shield  $117\mu$ , sides contouring coxae II then running between coxae II and III to form the posterolateral arms with a width of  $376\mu$ , posterior margin medially transverse for  $180\mu$  then sloping backwards lightly for  $75\mu$  on each side before running obliquely forward to the tips of the postero-lateral arms of the shield, with three pairs of very short ca.  $10\text{--}12\mu$  setae and one pair of lyriform pores, the anterior setae (sternal setae II) are  $28\mu$  from the anterior margin and  $56\mu$  apart, the other two pairs form a transverse row near the posterior margin with the medians  $60\mu$  apart and  $35\mu$  from the laterals, the pores are  $36\mu$  from setae II and  $103\mu$  apart; sternogynial shield as figured, as wide anteriorly as long  $146\mu$ , the sides widen out in line with the pores to a width of  $169\mu$  and then converge in a fairly even curve to the posterior apex, with the lyriform pores  $37\mu$  from the anterior margin and  $117\mu$  apart; mesogynial shield reduced and obscured; latigynial shields strap-like and contouring sternogynial shield as in other species; ventral shield large occupying most of the venter and coalesced with other shields except the anal, with a transverse posterior margin  $696\mu$  wide, with a number of rounded pores and a few minute setae; anal shield large, triangular,  $696\mu$  wide on the anterior transverse margin and  $336\mu$  long (deep) giving a ratio of width to length of  $2.07:1.0$ , paranal setae  $85\mu$  long.

*Gnathosoma* as in other species.

*Legs*—As in other species, I  $660\mu$ , II and III  $522\mu$ , IV  $600\mu$ .

*Allotype male*.—Of the same shape and dimensions as the female.

*Dorsum* as in the female.

*Venter*.—Tritosternum with bulbous basal part  $70\mu$  long by  $75\mu$ , and a pair of ciliated laciniae  $150\mu$  long; pre-sternal processes short and stumpy, turned in towards one another,  $47\mu$  long and  $23\mu$  wide with truncate apex; sterno-

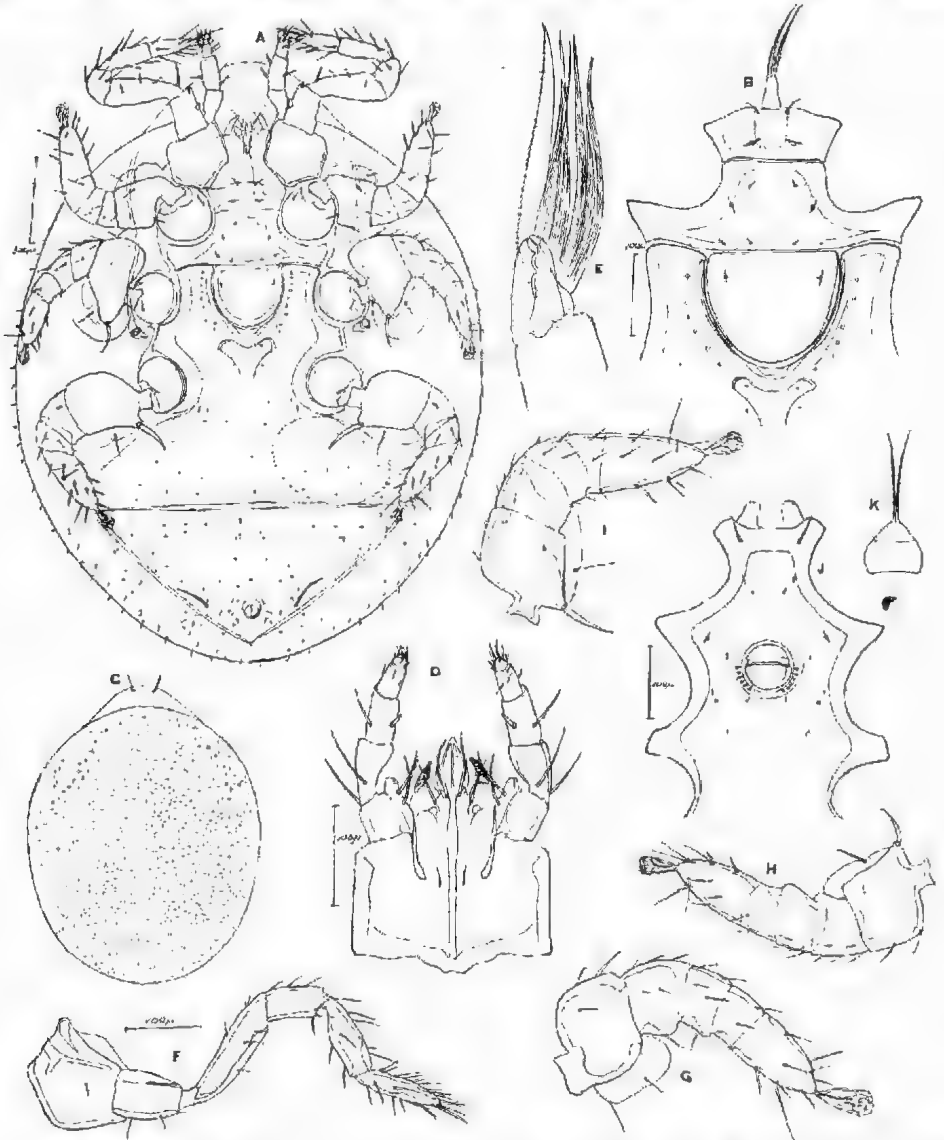


Fig. 13.—*Neofedrizzia vidua* sp. nov. A-I, Female: A, ventral view; B, tritosternum, sternal, sternogynial and latigynial shields and claviform processes enlarged; C, dorsal shield; D, gnathosoma and palpi; E, chelicerae; F, leg I; G, leg II; H, leg III; I, leg IV; J-K, Male: J, pre-sternal processes and sternal shield; K, tritosternum.

ventral shield as in other species, anterior margin concave,  $131\mu$  wide, with blunt obliquely truncate antero-lateral angles, sternal setae I  $50\mu$  long, a pair of small lyriform pores  $56\mu$  behind setae I and  $90\mu$  apart, another pair of long lyriform

pores  $90\mu$  behind the last and  $207\mu$  apart, several other rounded pores and minute setae, genital orifice between coxae II and III and  $94\mu$  wide by  $75\mu$  long with a series of six pores on each side around the basal half; anal shield as in the female with some pores and minute setae as well as the pair of paranal setae  $85\mu$  long, on the under-lap of the dorsal shield around the anal shield are a number of small setae.

*Gnathosoma* and *Legs*—As in female.

***Neofedrizzia brooksi* sp. nov.**

Text fig. 14 A-J

*Types*—Holotype male, allotype female and one paratype male from a Passalid, in rain forest, Eubanangee, near Innisfail, Queensland, 11th December, 1945 (J. C. Brooks).

*Description*—*Female allotype*—A moderately large species, with the general facies of the family, but the sides medially rather straight than rounded and slightly tapering backwards. Length of idiosoma  $1276\mu$ , width  $870\mu$ , ratio length to width =  $1.47:1.0$ .

*Dorsum*—Shield covering all the dorsum, and under-lapping the venter anteriorly to form the front margin of the camerostome, laterally confluent or coalesced with the large ventral shield and under-lapping from coxae IV to the end, the margins contouring the edges of the ventral and anal shields; in front of camerostome with a pair of setae  $56\mu$  long and ciliated.

*Venter*—Tritosternum with base  $70\mu$  long and subdivided, with paired ciliated laciniae  $140\mu$  long; jugular shield united medially to form a crown-like single shield,  $161\mu$  wide by  $56\mu$  long, posterior margin  $132\mu$  and straight, with a pair of recurved setae  $47\mu$  long and  $38\mu$  apart on the anterior margin flanking the base of tritosternum, with a pair of lyriform pores subposteriorly; sternal shield coalesced with endopodal shields of coxae II,  $140\mu$  wide anteriorly, scarcely narrowing to mid-line of coxae II and contouring coxae II to expand to a width of  $402\mu$  for the postero-lateral arms between coxae II and III, posterior margin straight medially for about  $228\mu$ , and then running slightly backwards for about  $95\mu$  on each side after which it turns sharply forwards to the extreme tips of the postero-lateral arms, with three pairs of setae to  $56\mu$  long and ? 2 pairs of pores, the anterior setae are in the antero-lateral corners and  $70\mu$  apart, the other two pairs (sternal setae III and IV) form a transverse posterior row in which the median pair are ca.  $60\mu$  apart and ca.  $30\mu$  from the laterals; sternogynial shield as figured, anterior margin straight and  $132\mu$  wide, sides expanding slightly to  $141\mu$  immediately behind anterior corners, then evenly rounded to apex, length of shield  $126\mu$ , with one pair of lyriform pores in antero-lateral angles; latigynial shields strap-like, widening a little in apical third, and contouring sides of sternogynial shield; mesogynial shield small, behind it are faint indications of broad vaginal sclerites; ventral shield coalesced with other shields, except anal, as in other species, posterior margin straight, transverse and  $520\mu$  wide; anal shield large, triangular,  $520\mu$  wide by  $250\mu$  long, ratio width to length  $2.08:1.0$ ; paranal setae missing.

*Gnathosoma*—Hypostome, labial cornicles, chelicerae and palpi as in other species of the genus.

*Legs*—As in other species, I  $475\mu$ , II  $420\mu$ , III  $420\mu$ , IV  $475\mu$ .

*Male holotype*—With the general facies and size of the female.

*Dorsum*—As in female.

*Venter*—Tritosternum with a bulbous basal part  $98\mu$  long by  $75\mu$  wide and subdivided near apex, with paired ciliated laciniae  $140\mu$  long; no jugular shield;

in front of anterior sternal margin with a pair of anteriorly directed processes  $47\mu$  long and  $24\mu$  wide turned outwards and apparently fixed basally; sternal, endopodal, ventral and exopodal shields coalesced, anterior margin medially concave and  $164\mu$  wide, the anterior pair of setae (sternal setae I) are long  $47\mu$  and  $70\mu$  apart, sternal setae II and III are minute, II  $56\mu$  from I and  $47\mu$  apart, III  $47\mu$  from II and  $60\mu$  apart; setae IV are in line with the middle of

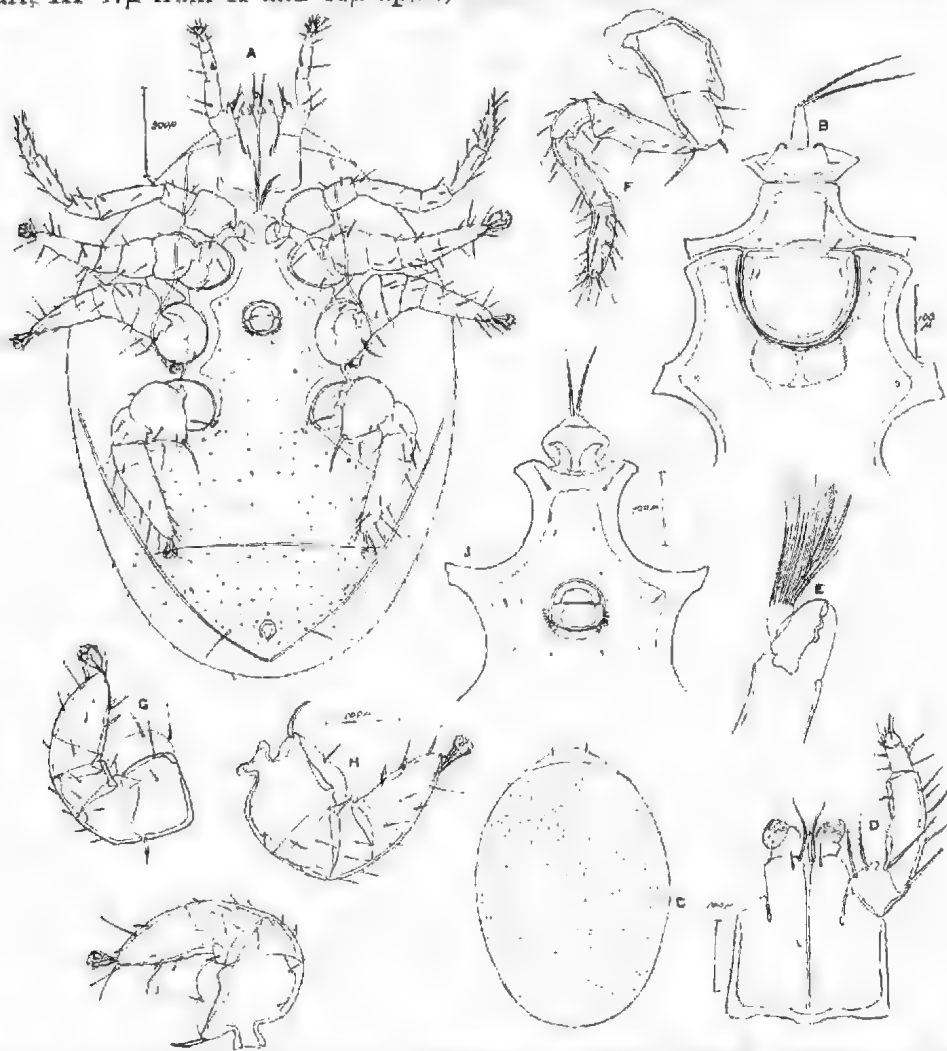


Fig. 14.—*Neofedrizzia brooksi* sp. nov. A-I, Female: A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields and claviform processes enlarged; C, dorsal shield; D, gnathosoma and palp; E, chelicerae; F, leg I; G, leg II; H, leg III; I, leg IV; J, Male tritosternum, pre-sternal processes and sternal shield.

the genital orifice and  $160\mu$  apart, with their attendant pores  $188\mu$  apart; the genital orifice is rather small, situated between coxae II and coxae III,  $10\mu$  wide by  $38\mu$  long, on the postero-lateral corners are a series of tubercles; anal shield as in female,  $520\mu$  wide and  $250\mu$  long, with numerous pores and a pair of long paranal setae.

*Gnathosoma and Legs*.—As in female.

*Neofedrizzia scutata* sp. nov.

Text figs. 15 A-J

**Types**—Holotype and 2 paratype females from a Passalid at Bulolo, New Guinea, Sept. 3rd, 1954 (coll. H.W.).

**Description**—*Female holotype*—A large species of the general facies of other members of the genus. Length of idiosoma  $1276\mu$ , width  $963\mu$ , ratio length to width 1.32:1.0.

**Dorsum**—Shield entire and under-lapping venter as in other species apparently without setae or pores.

**Venter**—Tritosternum with moderate thick basal part and paired ciliated laciniae; jugular shields coalesced medially to form a single crown-like transverse shield  $146\mu$  wide by  $52\mu$  long, with almost straight posterior margin, and the anterior margin indented medially to accommodate base of tritosternum, with a pair of long setae anteriorly and  $47\mu$  apart, and a pair of lyriform pores more posterior; sternal shield anteriorly slightly wider than posterior margin of jugular shield  $117\mu$ , sides narrowing between coxae II to  $103\mu$ , and then curving round coxae II to form the postero-lateral arms with a width of  $329\mu$  between coxae II and III, length of shield  $113\mu$ , posterior margin straight for  $126\mu$ , then produced posteriorly for a width of  $27\mu$  on each side, after which it runs obliquely forwards to the tips of the postero-lateral arms, furnished with three pairs of long  $33\mu$  setae and ? two pairs of lyriform pores, the anterior pair of setae (sternal setae II) are about in line with the middle of coxae II, the other two pairs (sternal setae III and IV) form a transverse row near the posterior margin, the median pair  $52\mu$  apart and  $42\mu$  from each lateral seta, the anterior pair of pores could not be seen; sternogynial shield as figured like an inverted cone with only lightly curved sides,  $211\mu$  wide anteriorly and  $160\mu$  long, with a pair of pores in the antero-lateral corners; the mesogynial shield reduced as figured; latigynial shields strap-like and contouring sides of sternogynial shield and rather hidden under the edges of the surrounding anterior arms of the ventral shield; ventral shield large and coalesced with other shields as in other species, the posterior straight transverse margin is  $784\mu$  wide and from its lateral ends a fine diagonal line runs inwards and forwards to the inside of acetabula IV; the anal shield is separated from the ventral by a transverse suture  $784\mu$  wide anteriorly and  $267\mu$  long, it carries a pair of setae submedianly and subanteriorly and a pair of longer paranal setae, as well as a number of pores.

**Gnathosoma**—Mouthparts, palpi, chelicerae and hypostome as in other species; labial cornicles two-segmented with apical segment and blunt hyaline thumb-like body with a small adpressed claw-like process subapically.

**Legs**—I 6-segmented, antenniform, fairly slender and angulated, tarsus without caruncle or claws, II-IV stouter, IV with curved spine at posterior angle, all tarsi with short pretarsus, caruncle and indistinct claws, I  $600\mu$  long, II  $464\mu$ , III  $523\mu$ , IV  $578\mu$ .

**Male**—Unknown.

**Remarks**—This species is described from the type specimens only. It is by far the largest of the species at present known and differs from the others as indicated in the key.

*Neofedrizzia laevis* (Canest., 1884)

*Fedrizzia laevis* Canestrini, 1884. Acari dell'Australia Atti Ist. Veneto, 2 Ser. VI, pp. 708-709, Tav. VIII, fig. 3.

This species is only known from a single male found in "a collection of insects" from Queensland made by the late Prof. Pulle of the University of Padova.

A free translation of Canestrini's description is as follows:

"Length 0.91 mm, width 0.66 mm. Known from a single specimen of the male only. It differs from the male of *F. grossipes* in that the genital aperture is placed somewhat further back between the third pair of legs; it is semicircular or almost circular. Also it differs in the epistome (tectum) which is in the form of a dentate spine approaching that of the Uropodids. The shape of the body is oval, posteriorly rounded. All the animal appears smooth; under a high magnification (Zeiss. Ocul. 2, Obj. D) it has very short setae in contrast to the two longer ones found on the anal shield on each side of the anal aperture."

From the above the ratio of the length to width of the idiosoma is 1.38 : 1.0. Interpolating from Canestrini's figure of the ventral surface, the anal shield has a width of  $425\mu$  and a length of  $190\mu$  giving a ratio of width to length of 2.23 : 1.0. The femur of leg IV is shown as short and broad, but the laminae and posterior strong curved spine are not observable.

He notes and shows in his figure that the genital orifice is placed far back between the third or even the third and fourth coxae. It is not clear in his figure whether there is a jugular shield present or not although it could quite easily be absent.

This would seem to be a valid species of *Neofedrizzia*, differing significantly in the position of the male genital orifice. In none of the many specimens examined during the course of this study have any males showing such a backward position of the genital orifice been seen.

#### *Neofedrizzia vitzthumi* (Ouds., 1927)

*Toxopeusia vitzthumi* Ouds., 1927. Ent. Ber., 7, 156, p. 228; 1928. Fauna Burutana. Acari, in Troubia., 7, suppl. 2, pp. 66-70, figs. 82-98.

This species was very fully described and figured from a single specimen (or ? specimens) from "in fungi", Wai Eno his Wai Temun, Buru, at 700-1000m.; 3rd Nov., 1922 (coll. L. J. Toxopeus). Only the female sex was found.

Although placed by Oudemans along with *strandii* in his genus *Toxopeusia* (*Fedrizzia*) it is readily seen from his drawings (1928) in spite of the lack of the male, that this species belongs to the new genus *Neofedrizzia* on the following features: (1) the femora of leg IV is short and stout, with laminae, and probably with the posterior curved spine although this is not obvious in the figure. (2) the sternogynial shield has the antero-lateral corners curved inwards, and (3) only one of the two long setae on the first free segment of the palp is ciliated and that shortly so.

According to the description, the idiosoma is  $745\mu$  long by  $570\mu$  wide giving a ratio of length to width of 1.3 : 1.0; interpolating from Oudemans's figures the anal shield is  $409\mu$  wide by  $145\mu$  or a ratio of width to length of 2.42 : 1.0; the sternogynial shield has the antero-lateral corners rounded inwardly so that the widest part is slightly behind the anterior margin and is  $92\mu$ , the anterior margin is  $80\mu$ , the sides are straight and parallel and the posterior rounded, it is  $109\mu$  long, or a ratio of anterior width to length of 0.73 : 1.0.

The species is otherwise quite distinct from the other species known from Australia and New Guinea as described in the present paper, and can be distinguished as in the key.

*Remarks*—Of the above species of *Neofedrizzia* it seems likely that *N. laevis* (Canest.) on the more posterior position of the genital orifice of the male, will ultimately require a new genus, but in the absence of the female it seems better

at present to retain it in *Neofedrizzia*. *Neofedrizzia scutata* sp. nov. is also an anomalous species within the genus. Apart from the unique dorsal scute, it is intermediate between *Fedrizzia* and *Neofedrizzia* in the shape of the sterno-

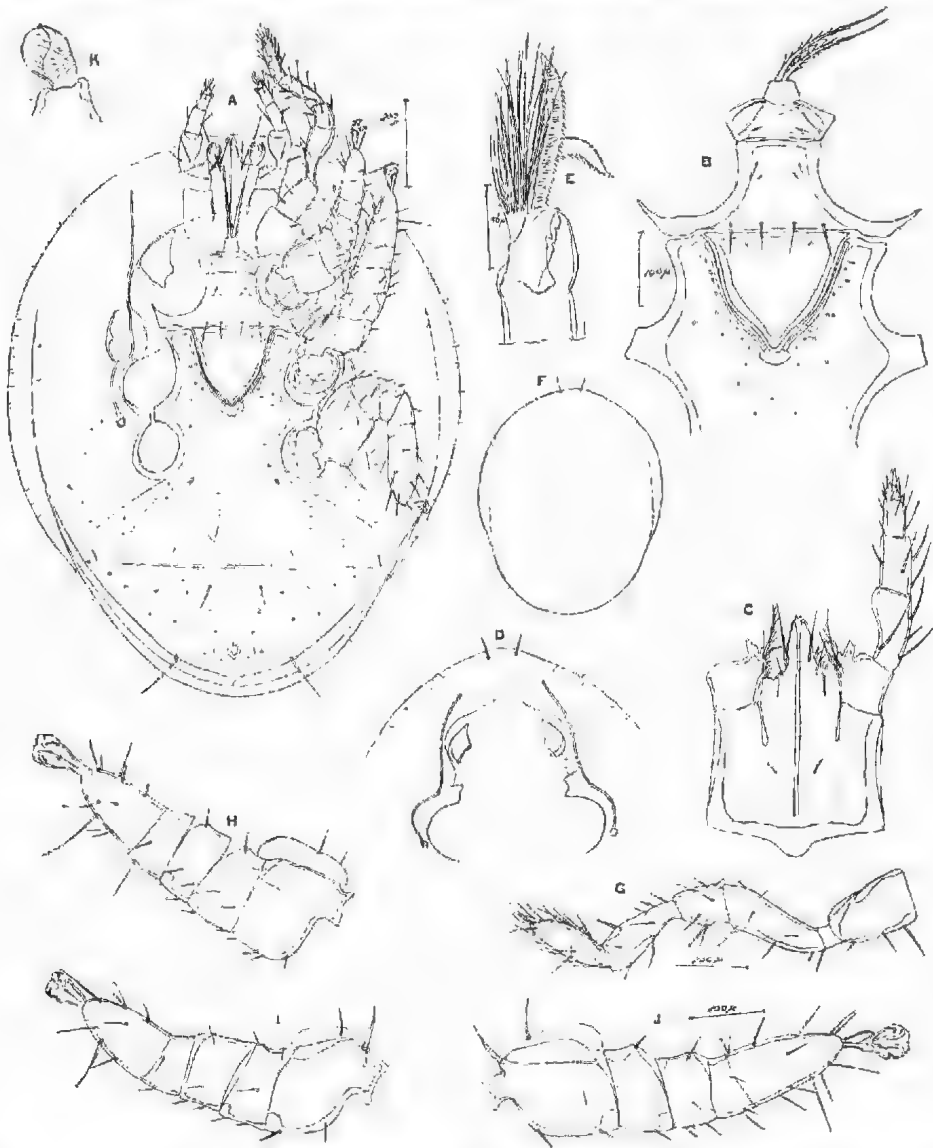


Fig. 15.—*Neofedrizzia scutata* sp. nov. A-K, Female: A, ventral view; B, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; C, gnathosoma and palp; D, camerostome showing axillar plates; E, chelicerae; F, dorsum; G, leg I; H, leg II; I, leg III; J, leg IV; K, labial cornicle.

gynial shield, which has the antero-lateral angles outwardly produced as in *Fedrizzia* and not evenly rounded as in all other species of *Neofedrizzia*. As our knowledge of the family increases this species will most likely require a new generic name.



Key to the species of *Neofedrizzia* gen. nov.

1. Male genital orifice between coxae III or between coxae III and IV. Length of idiosoma  $910\mu$ , width  $660\mu$ , ratio length to width =  $1.38:1.0$ . Anal shield ca.  $425\mu$  wide by  $190\mu$  long, ratio width to length =  $2.23:1.0$ . Anterior hyaline portion of dorsal shield small and crescentic. Female unknown.

*N. laevis* (Canest., 1884).

Where known males with genital orifice between coxae II or between coxae II and III. 2

2. Anterior hyaline portion of dorsal shield large, expanded laterally and posteriorly to about the level of anterior margin of anal shield, to form a distinct scute without pores or setae except the verticals. Sternogynial shield conical with lightly convex converging sides, wider anteriorly than long,  $211\mu$  by  $160\mu$ , ratio width to length =  $1.32:1.0$ , the antero-lateral angles are acute as in *Fedrizzia*. Anal shield  $784\mu$  wide by  $267\mu$  long, ratio width to length =  $2.93:1.0$ . Idiosoma  $1276\mu$  long by  $963\mu$  wide, ratio length to width =  $1.32:1.0$ . Male unknown.

*N. scutata* sp. nov.

Anterior hyaline portion of dorsal shield small, crescent- or sickle-shaped, not extending backwards beyond level of anterior edge of camerostome. Antero-lateral angles of sternogynial shield not acute, evenly rounded. 3

3. Anterior margin of sternogynial shield equal to or longer than the shield. 4

Anterior margin of sternogynial shield shorter than the shield. 6

4. Sternogynial shield as wide across anterior margin as it is long,  $146\mu$ , with its sides and posterior evenly rounded. Sternal setae II, III and IV minute. Anal shield  $696\mu$  wide by  $336\mu$  long, ratio width to length =  $2.07:1.0$ . Pre-sternal processes of male stout and short with truncate apex, and curved inwards; genital orifice with about 7 pores surrounding posterior half. Length of idiosoma  $1392\mu$ , width  $1020\mu$ , ratio length to width =  $1.36:1.0$ .

*N. vidua* sp. nov.

Anterior margin of sternogynial shield distinctly longer than the shield. 5

5. Pre-sternal processes of male curved outwards and bluntly pointed apically; male genital orifice flanked posteriorly by about 8 pores on each side. Sternogynial shield of female  $132\mu$  wide on anterior margin by  $126\mu$  long, ratio width to length =  $1.05:1.0$ . Anal shield  $520\mu$  wide by  $250\mu$  long, ratio width to length =  $2.08:1.0$ . Length of idiosoma  $1276\mu$ , width  $870\mu$ , ratio length to width =  $1.47:1.0$ .

*N. brooksi* sp. nov.

Pre-sternal processes of male short, bluntly rounded apically and curved inwards to one another; genital orifice of male without any pores flanking it on posterior half. Sternogynial shield evenly rounded laterally and posteriorly  $124\mu$  wide anteriorly and  $99\mu$  long, ratio of width to length =  $1.25:1.0$ . Anal shield  $406\mu$  wide by  $139\mu$  long, ratio width to length =  $2.92:1.0$ . Length of idiosoma  $812\mu$ , width  $638\mu$ , ratio length to width =  $1.27:1.0$ .

*N. canestrinii* sp. nov.

6. Sternogynial shield with straight parallel sides and broad rounded posterior, the anterior margin is  $80\mu$ , and its length  $109\mu$  ratio width to length =  $0.73 : 1.0$ . Anal shield  $409\mu$  wide by  $145\mu$  long, ratio of width to length =  $2.42 : 1.0$ . Idiosoma  $745\mu$  long by  $570\mu$  wide, ratio of length to width =  $1.3 : 1.0$ . Male unknown.

*N. vitzthumi* (Ouds., 1927),

Sternogynial shield not shaped as above.

7. Pre-sternal processes of male basally free, at least twice as long as wide, inwardly curved and bilobed apically. Sternogynial shield,  $146\mu$  long by  $126\mu$  wide on anterior margin, ratio width to length =  $0.86 : 1.0$ , with sides lightly convex and converging to a narrow rounded posterior. Anal shield  $520\mu$  wide by  $220\mu$  long, ratio width to length =  $2.36 : 1.0$ . Length of idiosoma  $1210\mu$ , width  $850\mu$ , ratio length to width =  $1.42 : 1.0$ .

*N. gayi* sp. nov.

Pre-sternal processes of male not as above, short and stout, bluntly truncate apically, curved inwards.

8. A small species, length of idiosoma  $893\mu$ , width  $638\mu$ , ratio of length to width  $1.4 : 1.0$ . Sternogynial shield  $103\mu$  wide on anterior margin by  $118\mu$  long, ratio of width to length =  $0.87 : 1.0$ . Anal shield  $352\mu$  wide by  $160\mu$  long, ratio width to length =  $2.2 : 1.0$ .

*N. cynota* sp. nov.

Large species, length of idiosoma  $1000\mu$  or more.

9. Large, somewhat elongate species, idiosoma  $1369\mu$  long,  $905\mu$  wide, ratio length to width  $1.5 : 1.0$ . Sternal setae I and II very long and slender, III and IV long but shorter than I and II. Sternogynial shield with lightly convex converging sides and rounded apex, slightly longer than it is wide on anterior margin,  $146\mu$  by  $141\mu$ , ratio width to length =  $0.96 : 1.0$ . Anal shield  $615\mu$  wide by  $302\mu$  long, ratio width to length =  $2.04 : 1.0$ .

*N. trugardhi* sp. nov.

Smaller species, length of idiosoma  $1000\mu$  to  $1200\mu$ .

10. Sternum of female with setae II-IV fine and slender and moderately long. Sternogynial shield bowl-like with evenly rounded sides,  $132\mu$  wide anteriorly by  $144\mu$  long, ratio width to length =  $0.92 : 1.0$ . Anal shield  $510\mu$  wide by  $244\mu$  long, ratio width to length =  $2.09 : 1.0$ . Pre-sternal processes of male, short, stout, apically truncate, about as long as wide, and bending inwards to one another. Idiosoma  $1160\mu$  long,  $770\mu$  wide, ratio length to width =  $1.5 : 1.0$ .

*N. camini* sp. nov.

Sternal setae shorter and not so fine. Sternogynial shield longer in proportion to width, anterior margin  $108\mu$ , length  $131\mu$ , ratio length to width =  $0.82 : 1.0$ , with lightly convex sides. Anal shield  $404\mu$  wide by  $202\mu$  long, ratio width to length  $2.0 : 1.0$ . Pre-sternal processes of male somewhat longer than wide, stout, apically truncate and only very slightly converging to one another. Idiosoma  $1020\mu$  long,  $696\mu$  wide, ratio width to length  $1.46 : 1.0$ .

*N. gorirossiae* sp. nov.

#### Genus PARAFEDRIZIA nov.

Separate jugular shield (tetartosternum) present in both sexes, consequently the male without the pre-sternal processes of *Neofedrizzia*. Sternogynial shield

of female widest across the anterior margin with outwardly directed antero-lateral corners as in *Fedrizzia*, sides not evenly rounded, hell-jar shaped with apical knob. One of the two long setae on basal segment of palpi in both sexes with 6-8 long branches, the other nude. Femur of legs II-IV short and broad with lamellae as in *Neofedrizzia* but without the strong curved spine at the posterior corner. Anal shield coalesced with ventral shield in both sexes.

Type *Parafedrizzia buloloensis* sp. nov.

***Parafedrizzia buloloensis* sp. nov.**

Text fig. 16 A-K

*Types*—Holotype female, allotype male and six paratypes of each sex from a Passalid in a rotten log at Bulolo, New Guinea, 3rd Sept., 1954 (coll. H.W.).

*Description*—*Female holotype*—A strongly chitinated dark brownish species, of ovoid shape but widest posterior of the middle in line with coxae IV. Length of idiosoma  $970\mu$ , width  $680\mu$ , ratio length to width =  $1.42:1.0$ .

*Dorsum*—Shield entire and covering the whole of the dorsal surface, anteriorly of coxae IV underlapping the venter and coalesced with ventral and exopodal shields, and anteriorly forming a camerostome, posteriorly of coxae IV it underlaps as a rather broad strip separated from the ventri-anal shield by a distinct strip of cuticle; dorsally the shield is furnished with numerous circular pores, a number of lyriform pores and many minute setae, on the anterior margin is a pair of vertical setae,  $117\mu$  long, ciliated and  $117\mu$  apart, on each side of these are two short setae and a similar pair in between, on the disc is an oval area with fewer setae outlined by a line of inwardly curved crescent-like markings as figured.

*Venter*—Tritosternum with base not much longer than broad as figured, with paired ciliated laciniae; jugular shield (tetartosternum) as figured, crown-shaped,  $117\mu$  wide by  $47\mu$  long (deep) with one pair of slender setae anteriorly,  $56\mu$  apart and about  $50\mu$  long, with a pair of lyriform pores  $42\mu$  apart; sternal shield as figured, anterior margin straight  $89\mu$  wide, sides contouring coxae II with shield narrowest in mid-line of coxae II to  $80\mu$ , then expanding between coxae II and III to a width of  $282\mu$  for the postero-lateral arms, posterior margin straight medially for a width of  $188\mu$  then curving posteriorly for  $30\mu$  on each side before running obliquely forwards to tip of postero-lateral arms, with three pairs of setae and one pair of lyriform pores, sternal setae II  $47\mu$  long and  $47\mu$  apart in the antero-lateral angles, III and IV shorter  $28\mu$  long in a transverse row near posterior margin, with the medians  $42\mu$  apart and  $28\mu$  from the laterals, pores  $33\mu$  behind setae II and  $52\mu$  apart, length of shield  $94\mu$ ; sternogynial shield hell-jar shaped, anterior margin  $179\mu$ , length  $132\mu$ , ratio width to length =  $1.35:1.0$ , sides sinuous and converging to apex as figured, with one pair of lyriform pores  $10\mu$  behind anterior margin and  $80\mu$  apart; latigynial shields strap-like contouring sides of sternogynial and partly hidden under inner edges of ventral shield; mesogynial shield reduced and partly obscured; ventral shield large, coalesced with the endopodal, exopodal and anal shields and occupying most of the venter with many small pores and small but obvious setae; the strip of under-lapping dorsal shield contouring the margins of the ventri-anal shield carries a row of about 5 fine setae on each side about  $24\mu$  long, the anus is situated in the posterior angle of the ventri-anal shield with the paranal setae very minute; the peritreme is thin and reaches to coxae I, with the stigma situated between coxae III and IV.

*Gnathosoma*—As in the other genera of the family; labial cornicles swollen with a small adpressed claw-like appendage; mandibles and chelicerae as figured.

**Legs**—As in species of *Neofedrizzia*, but the femora of legs II-IV without any strong curved spine at the posterior basal angle, I long  $464\mu$  and antennae-form, angulate, II-IV stouter with claws and caruncle, II  $440\mu$ , III  $440\mu$ , IV  $464\mu$ .

**Male allotype**—Of the same general facies as in the female. Length of idiosoma  $986\mu$ , width  $696\mu$ .

**Dorsum**—As in the female.

**Venter**—Tritosternum similar to that of female; jugular shield crown-shaped,  $113\mu$  wide by  $47\mu$  long (deep) with an anterior pair of slender recurved setae,

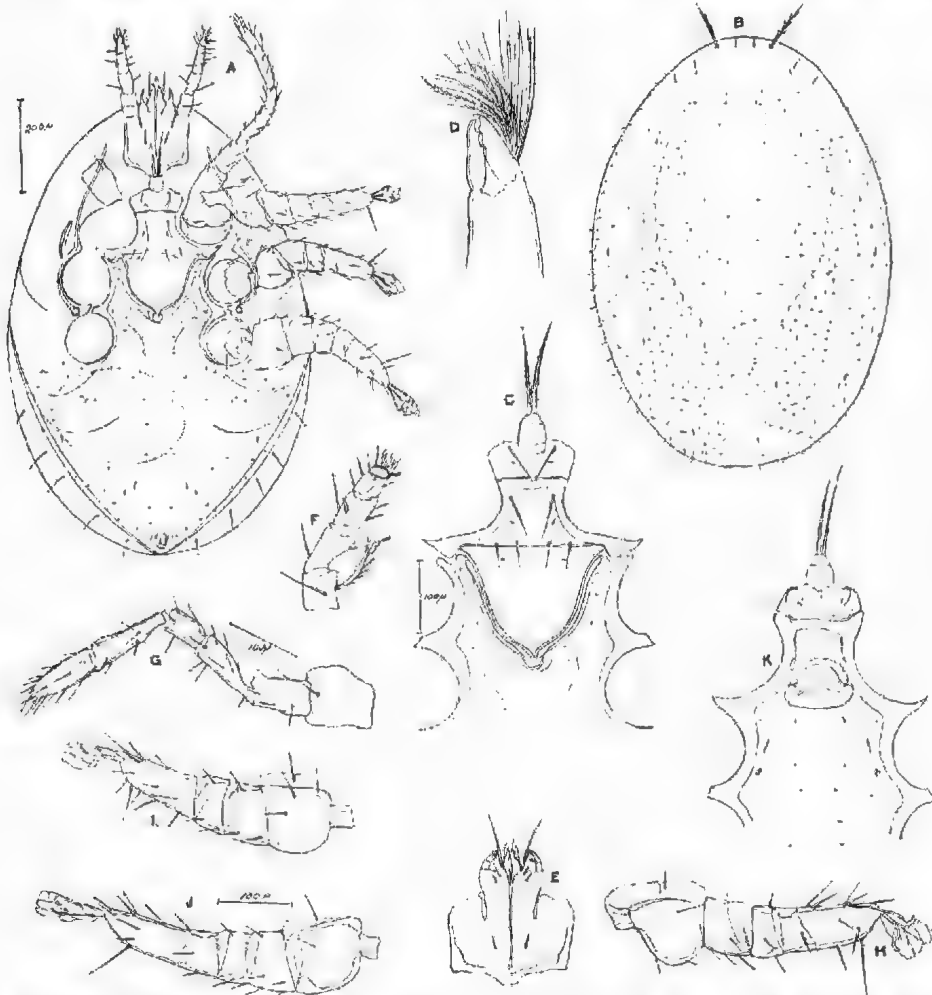


Fig. 16.—*Parafedrizzia buloloensis* g. et sp. nov. A-J, Female: A, ventral view; B, dorsum; C, tritosternum, jugular, sternal, sternogynial and latigynial shields enlarged; D, chelicerae; E, gnathosoma; F, palp; G, leg I; H, leg II; I, leg III; J, leg IV; K, Male tritosternum, jugular and sternal shields.

rather wide apart  $60\mu$ , and ca.  $50\mu$  long, with one pair of lyriform pores  $44\mu$  apart; sternal, ventral and anal shields coalesced together with endopodal and exopodal and the underlap of the dorsal shield as far back as posterior of coxae, and then separated from the under-lapping dorsal shield by a narrow strip of cuticle; with the genital orifice situated between coxae II and wider than long

94 $\mu$  by 66 $\mu$ , without any pores around the posterior half; with setae and pores as in Fig. 16 K; anterior width 108 $\mu$ , narrowest to 85 $\mu$  between coxae II and widest between tip of lateral arms between coxae II and III to 282 $\mu$ .

*Gnathosoma*—As in female.

*Legs*—As in female, I 464 $\mu$  long, antennaeform, II 406 $\mu$ , III 406 $\mu$ , IV 464 $\mu$ .

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N.B. Since this paper has been in press the following record has been noted.

*Fedrizzia gloriosa* n. sp. Dark brown, quite oval, size about twice that of the other two (*known*) species. Margin of body with equidistant minute setae. Mandibles in both sexes with small chelae, larger chela with penicillate process. All femora except first with wide marginal scale.

"Length 1250 $\mu$ , width 800 $\mu$ .

"Habitat on coleopteron of the family Passalidae. Australia, 'N.S.W.'. Coll. Cl. Froggatt."

The above is a free translation of the brief description published by Berlese. "Brevi diagnosi di generi et specie nuovi di Acari", Redia 6 (2): 376, 1910.

In view of our present knowledge of this family, such a brief description is specifically unrecognisable, pending a re-examination of Berlese's types which are probably in the Berlese collection in Florence.

All that can be said at this stage is that on the description of the femora of the legs it is probably a species of *Neofedrizzia*. It may be one of the larger species of this genus described in the present study.

# **LARGE ARCHAEOLOGICAL STONE IMPLEMENTS FROM HALLETT COVE, SOUTH AUSTRALIA.**

*BY H. M. COOPER*

## **Summary**

This paper records the occurrence at Hallett Cove, South Australia, of large stone implements both primitive in type and in manufacture, some forms of which are described and discussed. Reference is made to their similarity with material cultures discovered upon other long-abandoned native camp-sites in South Australia and also in Asia. It is suggested that at least some of these implements may represent one of the earliest periods in the succession of stone cultures employed by primitive man during his occupation of Australia and termed Kartan.

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[read 8 May 1958]

## SUMMARY

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## INTRODUCTION

In 1934 the author discovered large stone implements of crude manufacture upon cultivated land, recently ploughed, in a field below Hallett Cove Railway Siding, about ten miles south of Adelaide, re-examined and referred to by Tindale (1937). The area under cultivation has been extended considerably during recent years exposing, apparently, the whole extent of the former camp-site, with the exception of the western extremity where owing to the shallowness or absence of any surface soil, due possibly to erosion, implements and waste material lay exposed. Thirty subsequent examinations have been carried out, a total of more than 270 large implements being found. Successive ploughings provided favourable conditions for collecting.

The camp-site, about 200 feet above sea-level, is situated upon land gradually sloping towards the adjacent coastal cliffs and is bounded upon its southern side by a steep gully along the bottom of which runs a small stream fed by a permanent spring and swollen during the wet season by waters draining off hilly country further inland. Siltstone outcrops are exposed near this spring and also where the stream reaches the sea in its descent over several diminutive waterfalls. Both outcrops exhibit similar material to that employed in making the most efficient of the implements. A well-defined camp-site, exposed by ploughing and somewhat similar in situation to that below the railway siding, exists close by upon high ground above the southern side of the intervening gully already described. It yielded identical but fewer implements and may be considered a part of the larger one.

The surface of this field below the railway siding, at its eastern or upper end, consists of a compact red-brown earth which tends to become sandy in nature as it slopes towards the gully. The soil at the western end, where the main camp-site exists, is much lighter in colour, having an admixture of Kunkar Travertine, frequently nodular in form which it overlays in places to a very shallow depth. The surfaces of many of the implements are covered, wholly or in part, with a hard coating of calcareous matter (apparently derived from close association with the underlying Kunkar Travertine bed) which in places tends to mask the outline of secondary trimming. Additional implements were

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discovered, more sparingly, at several places upon the high ground facing Hallett Cove, more especially at its southern extreme above Field River. The camp below the railway siding, however, judged by the abundance of finished material and discarded waste, denotes the main point of occupation hereabouts during this period. It possessed by present indications, moreover, the essential requirements of a primitive people—a commanding view, a well-drained location and a permanent water supply.

## DISCUSSION AND CONCLUSIONS

The figured specimens, described herein, represent the principal types found upon the main camp-site below Hallett Cove Railway Siding and adjoining fields. There exist, in addition, many other large implements, roughly worked and nondescript in form which merely constitute a miscellaneous group of chopping tools supplementary to those represented by the drawings.

An examination of the 270 and more large archaeological implements discovered upon this camp-site indicates a standard of preparation ranging from the rudest attempts at primary and secondary flaking to secondary chipping, both simple and stepped, of a tolerably high order.

The graduated improvement in stone working may indicate that this material culture persisted at Hallett Cove for a considerable period of time.

It is somewhat difficult to conceive any reason or need for the employment of so much inferior material in the preparation of these implements generally and although the siltstones more compact in texture responded tolerably well it was difficult to control the direction of flakes it was desired to remove in the course of trimming those shaly in texture.

Fine-grained quartzite pebbles, which flake with an excellent conchoidal fracture and were highly prized and used almost exclusively by the recently extinct Kauria (Adelaide) Tribe, lie exposed at the foot of the sea cliffs immediately below the camp-site. Tindale (1957, 1) suggests, however, that access to this pebble bank may have been impossible in Kartan times owing to the existence of a talus which covered them. An excursion to the borders of the sea at that time by Hallett Cove camp dwellers in search of food, therefore, may have entailed a considerable journey. This section of the coast-line at present is undergoing serious erosion from seawards.

A few small implements and discarded cores, mostly of quartzites and Murundian in type, the most recent South Australian culture (Hale & Tindale, 1930) were found upon the Hallett Cove site but are easily recognisable. They are displayed as surface material at many places along the coast and are attributable to the Kauria people.

The archaeological large specimens from Hallett Cove, figured herein, indicate the former existence of a culture consisting mainly of general purpose chopping tool implements, semi-uniface in technique, and in addition a few which served as cleavers, saws or knives, skin scrapers and pounders. It is possible, therefore, that hunting, fighting and domestic weapons were correspondingly simple, being confined to roughly made spears, clubs, bark shields and some crudely mounted tools such as those described elsewhere in this paper. Pitting, bruising and battering, which are apparent upon the surfaces of many chopping implements, suggest their casual use as hammers when the need arose. This occurs frequently upon pebble choppers of the Kangaroo Island Industry (Cooper, 1943).

Twenty-five hammerstones of considerable size, many heavily battered or broken, also upper and nether millstones were found at the Hallett Cove site.

They consist mostly of water-worn stones and angular blocks of indifferent material which would suffice, however, to meet the cardinal needs of primitive man at this stage, including the trimming of the heavy, massive stone members of his archaeological implement culture, in which the fundamental principle of weight and bulk, as a means to an end, had not yet given way to lightness, sharpness and a wider assortment of types. The existence of many small hammerstones found in association with more recent cultures indicates, apart from other functions, a simple adjustment made necessary by the introduction and preparation of this series of new implements greatly reduced in size.

There is at the present time little information available with which to determine, with accuracy, the age of the large stone implements of South Australia, all of which are tentatively and broadly assigned to the Kartan Culture (Tindale, 1937). The approximate age of the Tartangan Culture, however (Hale and Tindale, 1930), consisting of small, well-executed implements, apparently much more recent, has been ascertained following Carbon 14 dating of stratified material from Tartanga and Cape Martin, the respective dates being  $6020 \pm 150$  B.P. and  $8700 \pm 120$  B.P. (Tindale, 1957, 2).

In the absence of any time dating figures a few observations may be made in the meantime which, when considered collectively, indicate that a considerable period of time must have elapsed upon Kangaroo Island—the Kartan Culture type locality—since the industry flourished and later ceased to exist there as also upon the mainland. Captain Matthew Flinders, R.N., who discovered this island in March, 1802, found it uninhabited, with the native animals totally fearless in the presence of man. Its typical pebble chopper industry, exposed by ploughing, was concentrated, but only so far as the present coastline indicates, around the banks and fringes of inland swamps and creeks in former heavily timbered country, now cleared. No skeletal material has been recovered. Examinations of favourable situations amid extensive series of recent sand-dunes, facing the shores in many places, have failed so far to reveal the existence of any camping grounds there. This would indicate that the island's large stone implement culture probably predated their formation. The period and entry path of Kangaroo Island's former dwellers as well as those of their departure—or local extinction—are unknown.

The Kangaroo Island pebble industry is represented at the Hallett Cove site by some examples, such as Fig. 8, and at other scattered places including Artipena Water and elsewhere (Cooper, 1943). Types similar to Figs. 5, 6, 7 and 14 appear upon Kangaroo Island, the adjacent mainland and further north. It is probable, therefore, that most if not all of this material is related to the same archaeological origin, although not necessarily to any one particular period.

Some former camps, if of sufficient antiquity, may now lie submerged within the present confines of the waters in the adjoining straits and the Gulf of St. Vincent.

The existence at Hallett Cove of many small pieces of slate, some showing evidence of wear and capable of scraping skins to serve as cloaks, although devoid of any regularity in shape, could indicate that at least a portion of the Kartan occupation may have coexisted with a time of rigorous climatic conditions, such as during the last Glacial Period. They may be early and crude equivalents of the beautifully-made, slender slate scrapers used by the recently extinct tribes of the Adelaide and adjoining regions.

During April, 1953, the author discovered upon the eroded summit of a red sand-dune, west of Port Augusta, a native hearth of burnt stones apparently quite recently uncovered. Twelve well preserved teeth, including molars and incisors, lay nearby in association with fragmentary bones, some showing evi-

dence of fire and others reduced to powder by complete disintegration. Mr. H. H. Finlayson, Hon. Curator of Mammals, South Australian Museum, who kindly examined the material, concludes that almost all can be reconciled with a small phase of *Diprotodon*, Owen, e.g. *D. minor*. Large stone implements, some similar to certain types figured in this paper, were scattered about upon the adjoining surface. Whilst not ignoring a possibility that the presence of the teeth and bones in this situation may be coincidental, the evidence of their existence amidst such surroundings is significant and suggests the site of an ancient tribal feast, or at least the place of its preparation.

If sufficient firm evidence is later forthcoming which confirms the contemporaneity of early man with *Diprotodon*, some of the thinner, heavy implements of the Kartan Culture, including large saws, cleavers and choppers, would prove efficient working tools for employment in the preliminary preparation of their hides and flesh.

Movius (1944) in his detailed survey of stratified material in Asia describes several types of large, crudely trimmed implements assigned by him to the Pleistocene Period which are identical with others figured in this paper. In stratified deposits discovered there the massive block and pebble chopper industries, dependent upon weight for efficiency in use, tend to appear at much earlier periods than the later groups of small artefacts with their specialised series of many types as represented in South Australia by the Murundian, Mudukian, Pirrian and Tartagan Cultures (Hale and Tindale, 1930).

The possible retention and continued manufacture by natives in subsequent periods of one or two implement types of the Kartan people, to perform certain work too heavy for their small artefacts, such as chopping through boughs and branches for the framework of their shelters, justifies some consideration. A few of the Kartan-made implements, indeed, may have been used either in their original state or with the addition of more advanced trimming. The temporary overlapping of some differing types, associated with two succeeding cultures, terminating with the extinction of the older, and also improvisation, such as that referred to above, have been noted in South Australia and elsewhere. Such instances, although of interest, appear to be merely of transient significance, in no way interrupting the establishment of the incoming stone culture.

Although the extent of the antiquity of the Hallett Cove implements and the Kartan Culture as a whole remains indeterminate, indications including those discussed above, suggest a period considerably earlier than the Tartagan dating of  $8700 \pm 120$  B.P. Future investigations, indeed, may reveal that this early heavy implement industry was one of long duration, necessitating its eventual division into separate periods or even into additional cultures.

Although the stone implements of the Kartan Culture may appear to us massive, rough and clumsy in comparison with the symmetry and beauty of the Pirri point, the polished axe-head and the microlith which followed after them, there is no reason for supposing that these imperishable products, developed by primitive man, failed in the accomplishment of all that the maker required of them in meeting the simple needs of his humble environment.

They represent, too, a great advance since the day when his ancestor sought to perceive upon the ground in some primeval forest, a random piece of rock with which to fashion laboriously, in default of anything better, a clumsy spear or rough-hewn club.

The inventiveness of man, such as that associated with the development of this early culture, as with so many others—primitive though it may seem to us

when judged by civilised standards—represents, nevertheless, an essential part of that vital structure, founded upon trial and error, perseverance and success so necessary in his endless struggle for survival.

### ACKNOWLEDGMENTS

It is desired to acknowledge, with appreciation, the assistance afforded by the following: Mr. A. E. Stone, Hallett Cove, for permission to carry out a prolonged and detailed examination of land below the railway siding whereon the main collection of implements was made; Miss M. P. Boyce, Artist, South Australian Museum, for the excellent drawings, Figs. 1-21 (Fig. 22 was drawn by the author) accompanying this paper; Dr. B. Daily, Curator of Fossils and Minerals in the same institution, for most helpful advice in identifying certain rocks employed by the natives; and Mr. V. P. Daly, Wilmington, for permission to search his fields adjoining the banks of Beautiful Valley Creek.

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### DESCRIPTION OF FIGURED SPECIMENS

The inset scale is the equivalent of six inches.

Figs. 1-17 are all semi-uniface trimmed implements

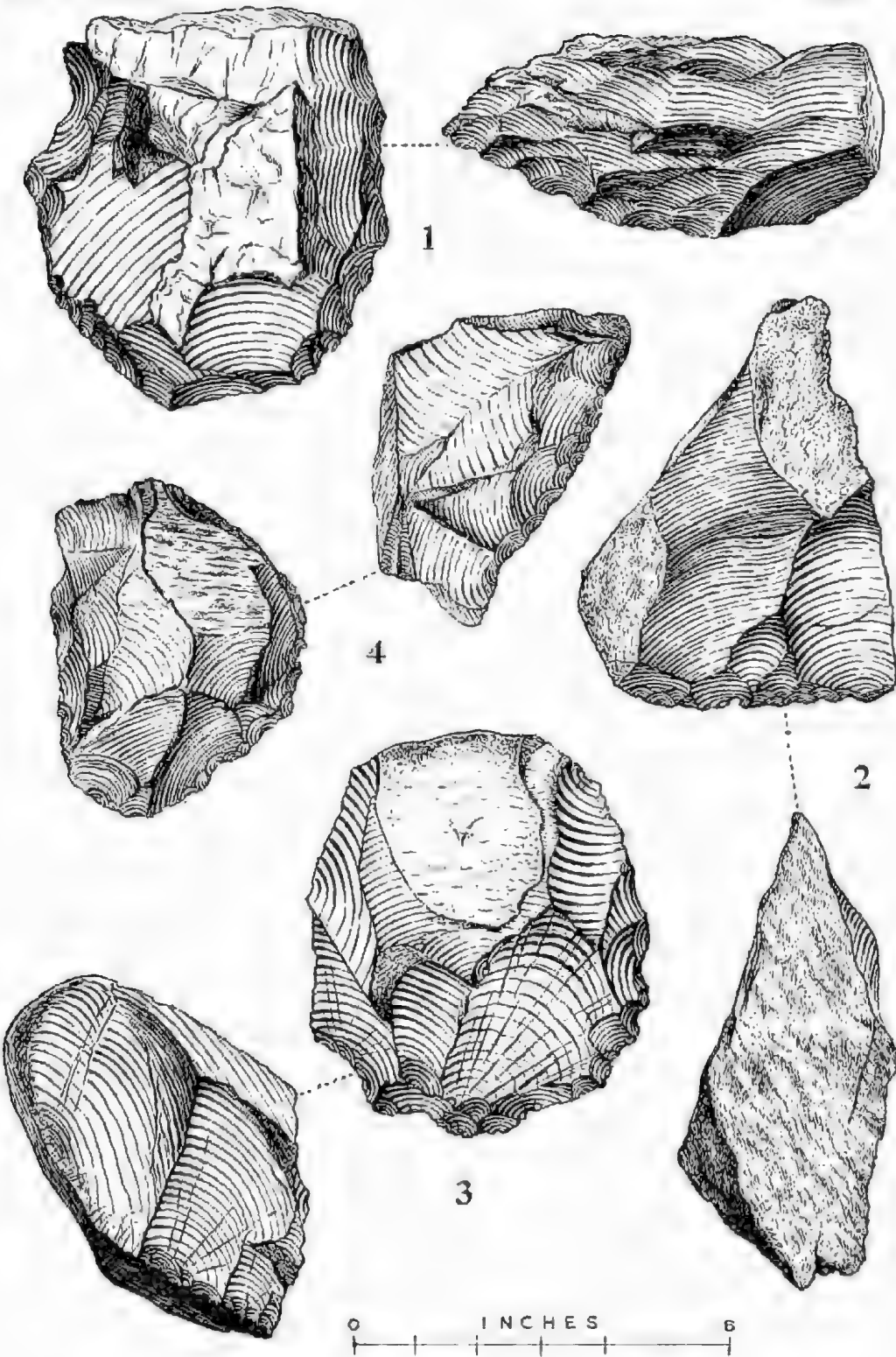
- Fig. 1.—A large highly patinated and weathered flat block with rough primary flaking along the frontal edge and two sides of its base margin. Weight 4 lbs.
- Fig. 2.—Large triangular block with secondary trimming confined to one straight chopping edge along its forward margin. It represents a type well established upon this camp-site although casual blocks of any suitable shape were used in its construction.
- Fig. 3.—Roughly trimmed from an irregular water-worn block around its base periphery except at the rear where the original cortex has been retained for convenience in use. Weight 5½ lbs. Figs. 1, 2, 3 and many others appear to be examples of two-handed chopping implements intended for working in the direction of the operator. The largest Hallett Cove example weighed 6 lbs.
- Figs. 4, 5 and 6.—Flat blocks, the latter two discoidal. All exhibit tolerably good secondary stepped trimming.
- Fig. 7.—A well-defined trimmed core in which the margin of the flat working base has been worn to such an extent by use and retouching as to be overhung by its apex. Its original form was possibly "horseshoe" in shape. *Vide* Cooper, 1943.
- Figs. 8 and 9.—Two pebbles with rounded and flat bases respectively; some stepped secondary trimming. Examples in this group are similar to the more poorly executed specimens existing in the Kangaroo Island pebble chopper industry (Cooper, 1943).
- Fig. 10.—Flat-based block with well-defined secondary stepped flaking. "Slug" shaped.
- Figs. 11 and 12.—Represent a type with working margins roughly triangular in shape and ending in a pronounced pointed extremity. Also made from pebbles. Fig. 12 is 1½ in. in thickness; made from a stone with upper and lower irregular faces.

Fig. 13.—A large cleaver or saw; it is a thin flake implement. Length 8 in.; thickness 1½ in. Cleavers or saws are relatively rare here.

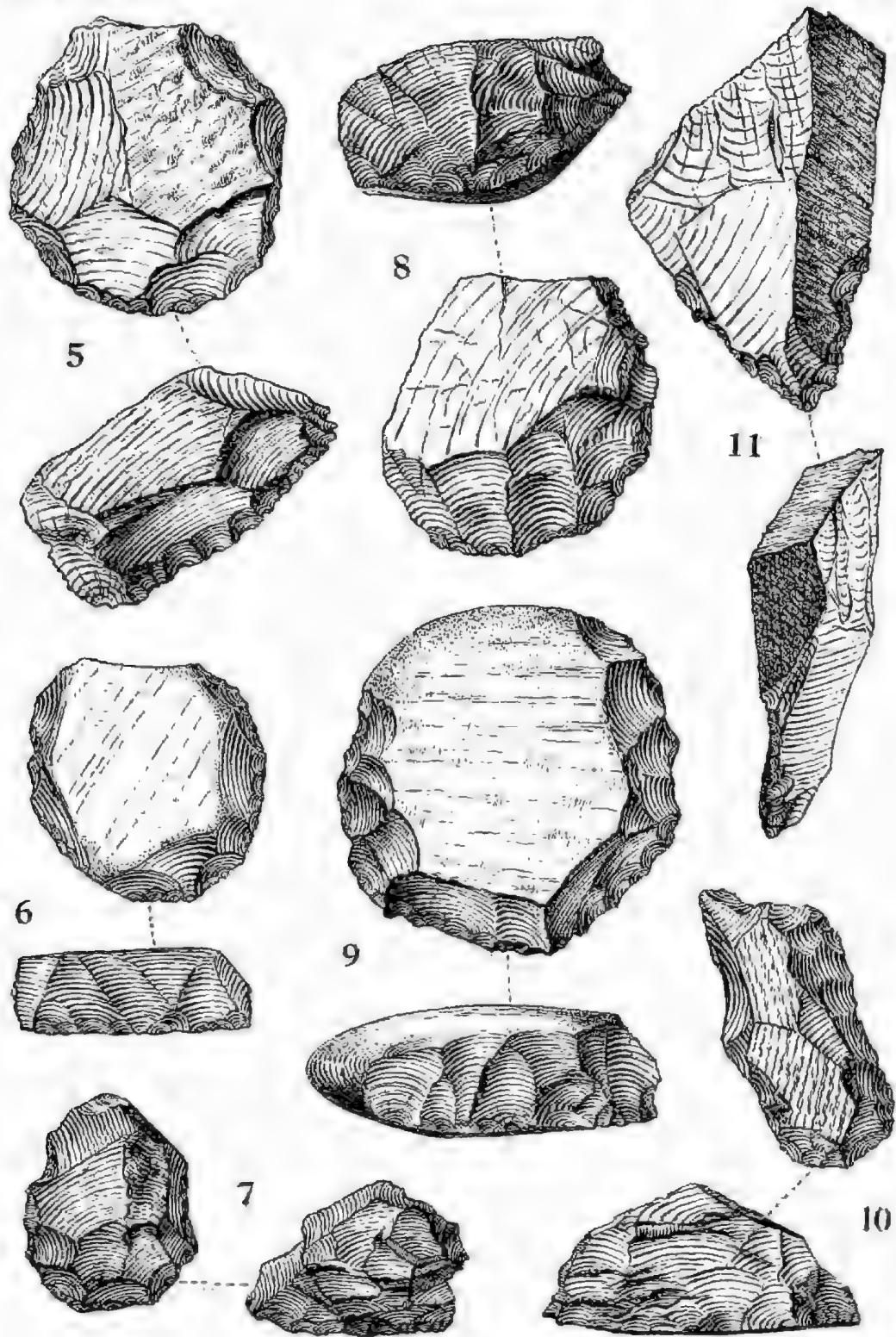
Figs. 14 and 15.—Two substantial flake chopping or scraping adzes with well developed percussion bulbs and striking platforms, both of which have been retained.

Figs. 16 and 17.—Appear to be smaller examples of types represented by Figs. 13 and 11.

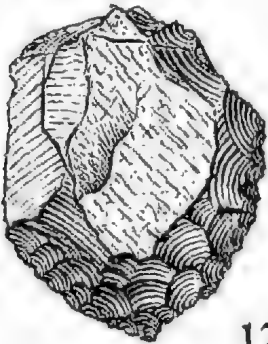
Figs. 18-22.—These five implements, representative of many others, display such crudeness in preparation that they appear to have escaped general notice and it was only the recurrence of so many similar examples which finally drew attention to their existence. There seem to be at least two types, Figs. 18, 19 and 22, serving as pounders and Figs. 20 and 21 for some form of scraping. They are finished, with few exceptions, from smooth yellowish soft siltstones of the Pre-Cambrian Marinoan Series, such as those present in the bed and upon the banks of the little stream previously referred to. No methodical preparation is indicated, although a little extremely rough primary trimming has been attempted in order to produce the desired shape. The natural form of the stone, with a little flaking here and there, is all that is evident in many cases. There are indications that at least some of the implements in these two groups were fastened to a crude form of wooden handle or withy because certain individuals exhibit a slight grooving due to possible wear whilst in others flakes have been roughly removed as if to make the haft more secure. The improvisation of some rough method of handgrip in certain cases, by means of gum or kangaroo hide, might also be considered. The softness and shaly nature of the stone often employed suggest their unsuitability for any purpose which involved undue stress. One possible use would have been in the preparation of skin cloaks as proposed above—Figs. 18, 19 and 22 for pounding and softening; Figs. 20 and 21 as scrapers. This group, with few exceptions, exhibits intense patination, severe weathering and patches of calcareous coating. Examples indicated by Figs. 20 and 21, if mounted and employed for cutting and scraping, would have been more efficient if hafted broadside on. An examination of the base of Fig. 18 discloses heavy wear upon one end of the working edge only, indicating that it was held in such a manner that pounding and hammering were concentrated upon that particular area. During November, 1957, the author found two isolated implements upon cultivated land alongside the banks of Beautiful Valley Creek, Wilmington, 200 miles north of Hallett Cove. One was similar to Fig. 3, the other being identical with Fig. 22, both in shape and in softness of material. It is possible, therefore, that this latter type may have considerable distribution.







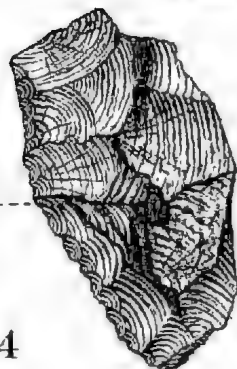




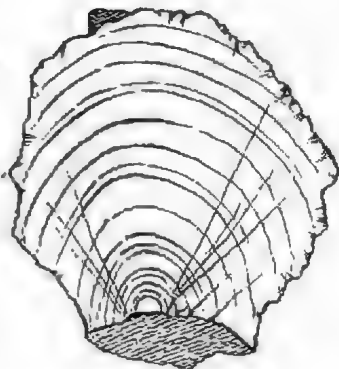
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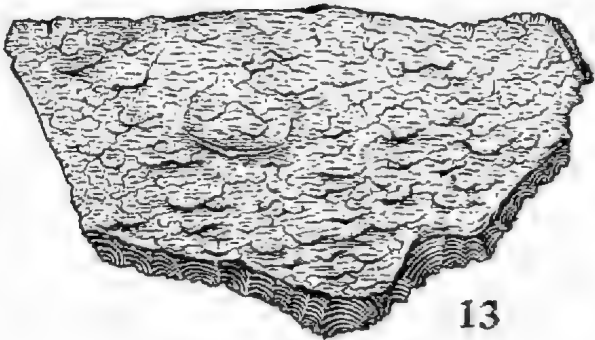
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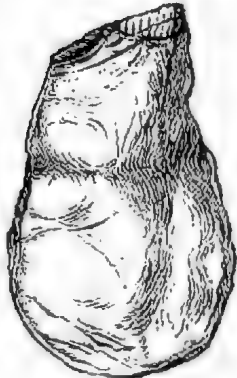
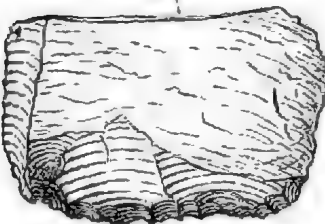
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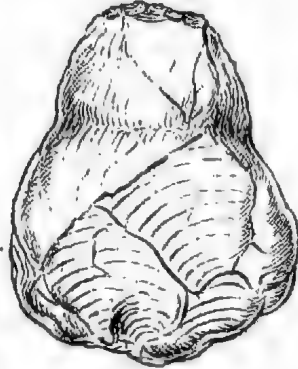
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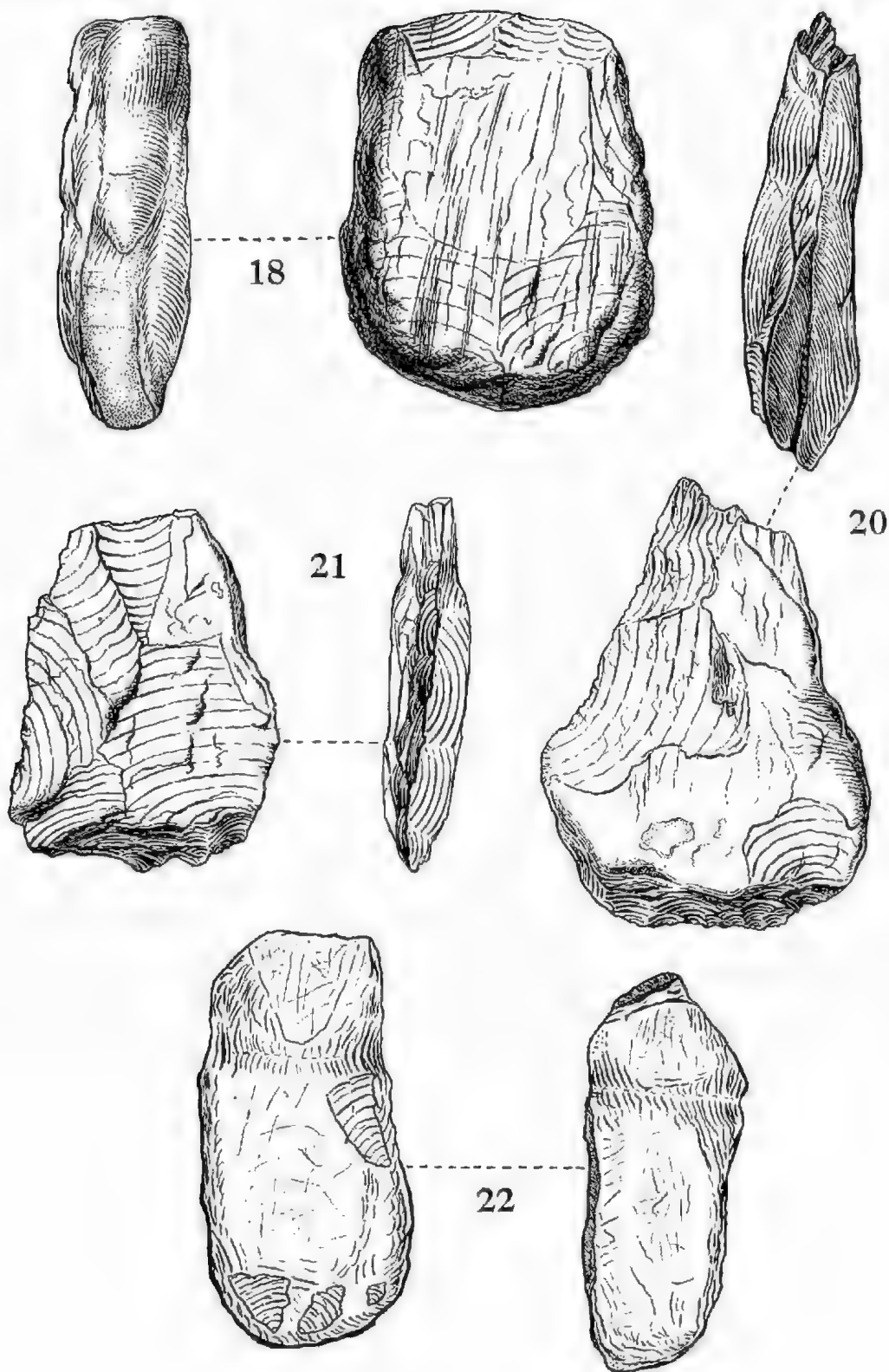


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# **THE KANMANTOO GROUP IN THE STRATHALBYN-HARROGATE REGION, SOUTH AUSTRALIA.**

*BY A. W. KLEEMAN AND B. J. SKINNER*

## **Summary**

This paper presents the results of structural mapping of the Kanmantoo Group in the area north and south of Kanmantoo township. The mapping shows that the Nairne Fault does not exist. The Kanmantoo Group lies conformably on the Marinoan series of the Adelaide System and the whole succession was folded in post-Kanmantoo time.

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[Read 12 June 1958]

## SUMMARY

This paper presents the results of structural mapping of the Kanmantoo Group in the area north and south of Kanmantoo township. The mapping shows that the Nairne Fault does not exist. The Kanmantoo Group lies conformably on the Marinoan series of the Adelaide System and the whole succession was folded in post-Kanmantoo time.

## INTRODUCTION

The area described in this paper lies on the eastern side of the Mt. Lofty Ranges, from Strathalbyn in the south to Harrogate in the north. In this region a vast thickness of generally fine-grained, dark grey rocks outcrop. Originally sandstones, greywackes and siltstones, they have been metamorphosed into micaceous quartzites, arkoses, quartz-felspar-mica schists and andalusite-staurolite schists. This group of rocks lies to the east of, and stratigraphically above, a series of rocks which are correlated with the rocks of the Adelaide System, typically exposed on the western slopes of the Mt. Lofty Ranges (Sprigg, 1942, 1946; Howchin, 1929).

Woolnough (1908), in referring to the rocks he saw on the eastern slopes of the Mt. Lofty Ranges, coined the name Barossian and misled by their metamorphism, believed them to be Archaean in age. Howchin, on the other hand, considered all of the rocks east of the core of the ranges to belong to the Adelaide System and correlated the Barossian of Woolnough with the upper portion of the Adelaide System.

In 1953 Sprigg and Campana gave the name Kanmantoo Group to the upper portion of the post-Archaean sequence in the eastern Mt. Lofty Ranges. Although the name Barossian has precedence, it is not advocated on the grounds that its reintroduction would cause unnecessary confusion.

The Kanmantoo Group, as generally understood from the definition by Sprigg and Campana (1953), consists of greywackes and micaceous quartzites with minor siltstones and shales in contrast to the quartzite, shale, limestone association of the Adelaide System. Sprigg and Campana stated that the Kanmantoo Group lay conformably above Lower Cambrian Strata, which in turn lay above the Adelaide System. However, for the whole distance from Birdwood to near Macclesfield, the Kanmantoo Group was supposed to be thrown against the Adelaide System by a fault, generally called the Nairne Fault (Sprigg *et al.*, 1951). The normal sequence of beds could supposedly be seen in the Macclesfield Syncline and also in the Angaston region. We do not propose to deal with the Angaston area in this paper.

In 1956 Campana and Horwitz disagreed with the fault hypothesis of Sprigg, mainly on the basis of mapping on the Milang and Yankalilla Sheets, and suggested that the boundary between the two groups of rocks was a transgression

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and that the Kanmantoo Group was laid down directly on the eroded surface of the Adelaide System rocks.

To attempt to resolve these conflicting hypotheses, and to further an interest in the Nairne Pyritic Formation, we have studied the Kanmantoo Group in the area outlined in the map (Fig. 1). This map is on a relatively small scale, but the more detailed maps are lodged in the Geology Department, University of Adelaide. Much of the mapping has been very detailed and a complete presentation of the data could only be effected on a scale of 2 inches to the mile.

### THE NAIRNE PYRITIC FORMATION

Pyrite and pyrrhotite bearing schists and quartzites outcrop for at least 65 miles along the regional strike. These beds have been the subject of a more detailed study (Skinner, 1958) and are believed to be true sedimentary deposits and not subsequent replacements of favourable horizons. The pyritic sediments as a whole have been called the Nairne Pyritic Formation though two main sulphide bearing units and several minor ones exist within the formation.

We have followed the pyritic beds from near Harrogate to within a few miles of Strathalbyn. Over this whole distance the pyritic beds can be traced by the characteristic "boxwork" in the weathered and ironstained outcrops. The width of the pyritic bands varies greatly. At Shephard Hill the main or lower band is 400 feet wide and another band, about 1500 feet higher in the sequence, is only about 50 feet thick. The lower band persists strongly for about 8 miles to the south, but 2 miles south of Barker Creek it pinches out, and after several reappearances finally disappears at a point north-east of Tinpot. The upper band reaches a thickness of 200 feet and can be traced as a strong horizon to beyond Tinpot, about 2 miles further south than the lower band. It then thins out to a width of only a few feet and cannot be traced with certainty for about half a mile. It reappears as a thin horizon and then thickens to about 200 feet again, 5 miles north of Strathalbyn. After about a mile it again becomes thin, and remains so until it finally disappears  $1\frac{1}{2}$  miles north of Strathalbyn. The breaks in continuity are due to patches of alluvium and deep soil cover, as well as thinning of the beds.

Both the upper and lower bands can be followed as continuous horizons from Harrogate to near Tinpot with only minor breaks due to alluvium in creeks. They are always conformable with the other sediments and mineralogical studies suggest that the sulphide and silicate minerals are compatible phases. This leaves no doubt that the pyrites is an original sedimentary deposit. At places a third or even a fourth band appears either between the two main bands or above the upper band. These minor bands are never greater than 10 feet thick and are very limited in distribution.

North of Harrogate, White (1956) (see also White and Thatcher, 1957) followed the Nairne Pyritic Formation till it meets the Bremer Fault to the east of Birdwood. He also mapped it east of the Bremer Fault, south of Rockleigh. Two bands of pyritic schist re-appear just to the west of the Bremer Fault south-east of Harrogate, and are believed to be the Nairne Pyritic Formation.

Near Macclesfield, pyritic beds were first met in a tributary of the Angas River a mile south of the town. In the creek sections the beds still retained much of their original pyrite, but on the hill slopes only the weathered rock could be seen. From here the rocks can be traced south, with several small breaks, till they pass under the Recent (and Tertiary) cover south-west of Strathalbyn. This pyritic bed dips to the west and must obviously lie on the west limb of an anticline, as was confirmed by structural mapping in the core

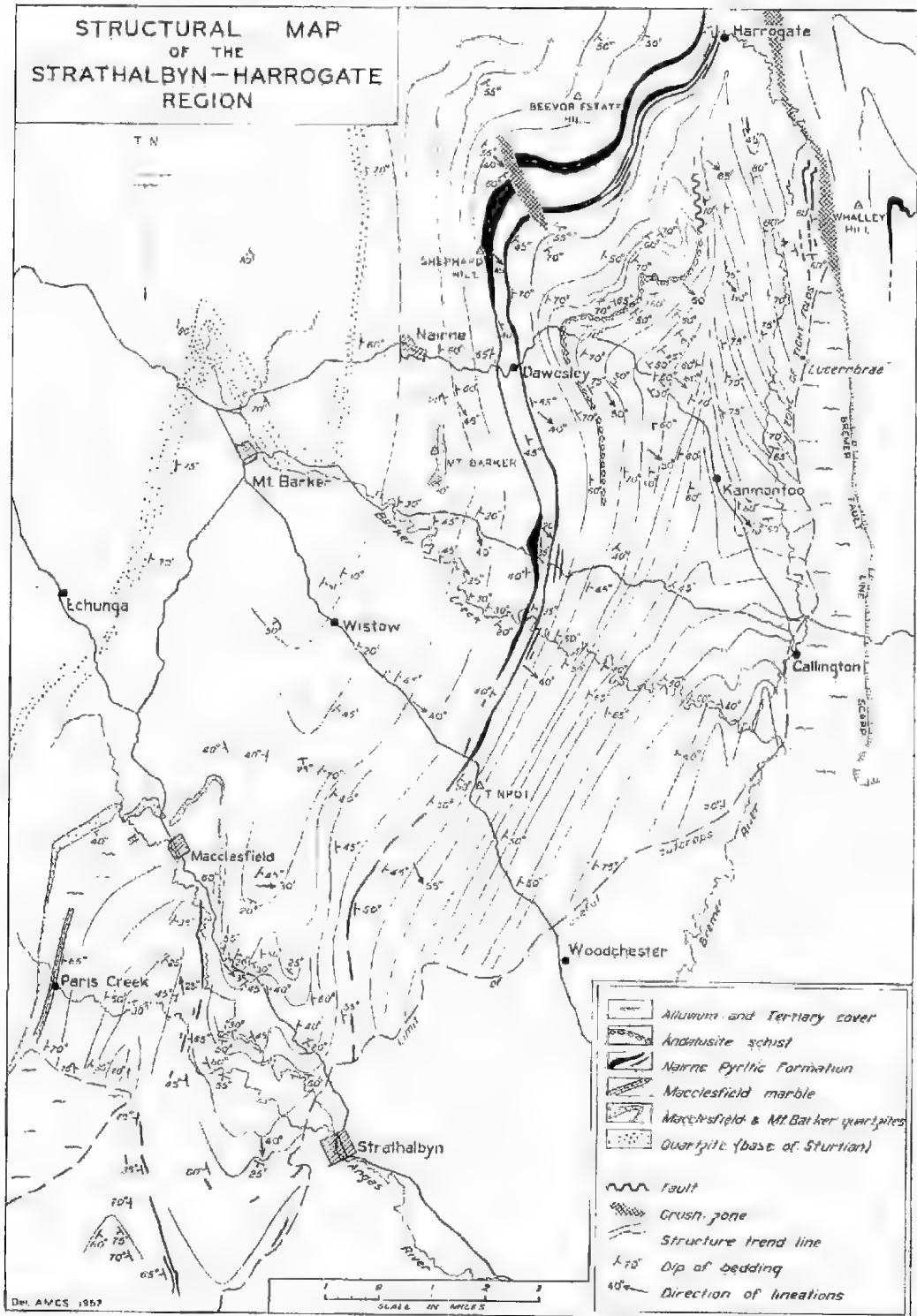


Fig. 1.

of the anticline. There is little doubt that this is the Nairne Pyritic Formation. The gap in outcrop around the nose of the Strathalbyn anticline is small.

The wide extent, the continuity and excellence of outcrop make the Nairne Pyritic Formation an excellent marker horizon in mapping the structures of the Kanmantoo Group. It is the only satisfactory marker horizon in the group, and appears to separate two series of rocks of somewhat differing lithology. Consequently, it is convenient to discuss the rocks above and below the Nairne Pyritic Formation separately.

### THE ROCKS BELOW THE NAIRNE PYRITIC FORMATION

Over most of the area mapped the beds immediately below the Nairne Pyritic Formation are massive cross-bedded micaceous quartzites and arkoses. The Barker Creek cuts a magnificent section through these beds. Here the cross bedding is on a large scale, the individual units being about 2 to 3 feet thick in many instances. The quartzite of Mt. Barker Summit appears to be only a local lens of pure quartzite near the base of this formation. Small outcrops of glassy quartzite south of Mt. Barker Summit also appear to be local lenses near the base of the massive cross-bedded quartzite.

Below the massive cross-bedded quartzite, which is at least 2000 feet thick in Barker Creek, there are quartz-felspar-mica schists, mica schists, bands of andalusite and andalusite-staurolite schists ("Paringite" of Woolnough), thin quartzites and a few lenses of marble and of calc-silicates. These rocks do not outcrop well and underly a great belt of fertile agricultural land between Mt. Barker town and Macclesfield. Below this sequence comes a prominent group of quartzites which Sprigg and Wilson (1954) placed at the base of the Sturtian Series.

Near Macclesfield the Nairne Pyritic Formation is underlain by about 1100 feet of quartz-felspar-mica schists (impure arkoses) followed by a thin band of quartzite, some of it micaceous, known as the Macclesfield Quartzite. Below this again comes more quartz-felspar-mica schist followed by mica schists and andalusite-staurolite schists. The micaceous quartzite and arkoses are not so conspicuously current bedded, nor are they as thick as in the Barker Creek section, but they are undoubtedly the same horizon. There is, on the other hand, a strong development of the andalusite-staurolite schist forming the core of the Strathalbyn Anticline, whilst a similar thickness of andalusite-staurolite schist is not found in the Barker Creek. It is possible that the thickening of these rocks in the core of the anticline is due to their plasticity during tectonic deformation rather than a sedimentary thickening since they are much contorted in the core of the fold.

There is no evidence to suggest that the Macclesfield Quartzite lies at the same horizon as the quartzite of Mt. Barker Summit. It is, in fact, probable that the Macclesfield Quartzite occurs near the middle of the micaceous quartzite horizon and the Mt. Barker quartzite at the base, but the position is complicated by a thickening of the micaceous quartzite horizon as it goes north.

Calcareous beds are found at several levels below the Nairne Pyritic Formation, but none can be traced far along the strike. In the northern part of the area there is a calc-silicate band—a diopside-seapolite rock—near the base of the micaceous quartzite horizon. It occurs on the Callington road south of Mt. Barker Summit, but can only be traced a few hundred yards. South of Macclesfield in the east limb of the Macclesfield Syncline, there is a small outcrop of calc-silicate rock a few hundred feet below the Nairne Pyritic Formation and above the micaceous quartzite. The position of this calc-silicate corresponds roughly with the Macclesfield Marble which has been mapped on the west limb of the Macclesfield Syncline. On the west limb of the syncline the



marble is first seen south of Paris Creek, emerging from below Tertiary sands and laterites, and can be traced easily to about 2 miles north of Paris Creek where it is again obscured by sands and laterites. It is seen again just west of the township of Macclesfield as a small outcrop. Another marble band occurs at the base of the Marinoan as defined by Sprigg and Wilson (Echunga Sheet). It, too, can be seen only in Bull Creek west of Paris Creek and in three places in the north. We have seen this in several places, but we have not extended our mapping far enough down into the Marinoan to correlate its various occurrences.

There is no evidence to suggest that there are any continuous marble beds in the area investigated. Rather, the evidence suggests that the marble beds occur as small lenses, possibly at definite horizons, but not with sufficient certainty to allow safe correlation over large distances.

Extensive calc-silicate horizons occur in the Woodside region but all of these are below the cross-bedded micaceous sandstone and we have not mapped them.

### THE ROCKS ABOVE THE NAIRNE PYRITIC FORMATION

The sediments above the pyritic formation are in general more micaceous and finer-grained than those below. The original sediments may fairly be described as fine-grained greywackes and siltstones with minor shales. The bulk of the rocks are quartz-felspar-mica schists, representing the greywackes and siltstones. The shales, however, have produced schists containing micas, andalusite, staurolite, feldspars and quartz. The andalusite schists are often very conspicuous as they sometimes contain andalusite crystals up to an inch in length. The development of large andalusite crystals is confined to the cores of the folds. On the limbs of the folds the andalusite schists are generally fine-grained and inconspicuous.

The first notable andalusite schist occurs about 7000 feet above the lowest pyrite band. The base of this bed can be mapped for several miles in the nose and on the western limb of the syncline near Dawesley. It is obvious that the andalusite schist is greatly thickened in the nose of this syncline because the outcrop is much wider along the road than it is further to the north or south. In the Barker Creek section only a few narrow bands of andalusite and andalusite-staurolite schist are met. It is possible that in the area east of Dawesley these schists reach their maximum development and that to the south they grade laterally into mica schists. Higher in the sequence these peraluminous beds grade up into normal mica schists and then into fine-grained quartz-felspar-mica schists which persist to the top of the exposed section. Small bands, however, are found at several places in the Barker Creek and, as in the Dawesley Syncline, they have been greatly thickened and contorted in the Callington Syncline. It is with the structurally thickened andalusite schists that the Callington-Kanmantoo inines are associated.

The andalusite schists above and below the Nairne Pyritic Formation cannot be distinguished in hand-specimen. They are always incompetent relative to the quartz-felspar-mica schists and the quartzites, and consequently show extreme contortion and thickening in the noses of the folds. On the limbs they are thin beds which make poor outcrops and consequently they are not satisfactory marker horizons.

### METAMORPHISM

The greywackes and siltstones which form the bulk of the rocks in the Kanmantoo Group have recrystallised to fine-grained quartz-felspar-mica schists. All of these rocks show the original bedding, and where foliation is present it

generally follows the bedding. As in the Tungkillo-Palmer area (Kleeman and White, 1957) the mica flakes often have a preferred orientation which differs from the bedding plane, but this rarely develops a foliation plane at an angle to the bedding. In the more micaceous rock types, however, originally shales, the bedding is often obscured by axial-plane foliation.

The peraluminous shales have recrystallised to mica schists in which andalusite, staurolite, kyanite, garnet and sillimanite occur. Sillimanite is only known from near Harrogate in a sillimanite-andalusite-muscovite-biotite rock and kyanite in a similar assemblage from Shephard Hill. Andalusite and staurolite, both together and separately, occur over the whole area wherever rocks of a suitable composition occur. White (1956) has shown that the sillimanite-muscovite assemblage is stable in the area north-east of Harrogate, and it is probable that there is a general increase in the grade of metamorphism from the S.S.W. to the N.N.E. This is borne out by the absence of andalusite and staurolite to the south-west of Paris Creek west of the mapped area. However, andalusite, staurolite and garnet are to be found only a few miles north-west of Strathalbyn.

The prominent andalusite crystals in the andalusite schist give the rock a more highly metamorphosed appearance than the surrounding fine-grained quartz-felspar-mica schists. The copper mines of the Kanmantoo-Callington area are associated with andalusite and andalusite-staurolite schists and this led Dickinson (1942) to suggest that the copper mineralisation was associated with "highs" of metamorphism. There seems, however, no evidence to support this. The quartz grains in both the andalusite schists and the quartz-felspar-mica schists are approximately the same size, and the coarse-grained look of the former rock is due solely to the large andalusite crystals and very obvious staurolite and garnet crystals. The difference in appearance between the andalusite schists and quartz-felspar-mica schists is therefore due to small differences in original composition and has nothing to do with degree of metamorphism.

We believe that mineralisation in the Kanmantoo Group, other than the Nairne Pyritic Formation, is always associated with the andalusite and andalusite-staurolite schists and is localized by shearing or extreme contortion within the incompetent andalusite and staurolite-andalusite schists. The Kanmantoo-Callington mines are the most prominent group, but many others do occur. The most outstanding of the other mines is the Wheal Ellen Mine, 5 miles north of Strathalbyn. The mineralisation here is confined to a thin band of garnet-staurolite and andalusite-mica schists enclosed in a massive series of fine-grained quartz-mica-felspar schists. Although the silicate minerals here are the same as those found in the Kanmantoo Mines area, there is no spectacular development of large crystals since the Wheal Ellen is on the limb of a large syncline. Sprigg and Wilson (1954) have mapped the Wheal Ellen as occurring in a pyritic schist. The pyrite in this case is associated with the later mineralisation and the rocks bear no resemblance to the Nairne Pyritic Formation nor do they appear to be in any way associated with the Nairne Pyritic Formation. It is unfortunate that Sprigg and Wilson did not satisfactorily differentiate between the two very different rock types on their map.

## STRUCTURE

The Kanmantoo Group lies on the eastern limb of the "Mt. Lofty anticlinorium" (Campana, 1955). This structure is overturned to the west due to lateral compression from the east. Our mapping has shown no recognisable break in deposition between the Adelaide System and the Kanmantoo Group and

demonstrates that the two have folded together as one unit. The east limb of the anticlinorium between the Archaean core of the ranges and the Bremer Fault is diversified by two synclines and an anticline. The Bremer Fault is believed by Kleeman and White (1956) to be the sheared west limb of another anticline and a further succession of synclines and anticlines occur to the east of the Bremer Fault. The structures east of the Bremer Fault will not be discussed further in this paper.

The syncline nearest to the Archaean core — the Macclesfield Syncline — is well shown by the outcrop of the Macclesfield Quartzite at the top of the Adelaide System and by the quartzites at the base of the Sturtian Series lower down in the Adelaide System. The Macclesfield Quartzite is broken in the trough of the syncline and there is the suggestion of one, perhaps two, minor anticlines modifying the major syncline.

The major anticline — the Strathalbyn Anticline — is shown by the fold in the Sturtian quartzites near Mt. Barker town, and by the presence of the Nairne Pyritic Formation on both limbs of the fold near Strathalbyn. Unfortunately the pyritic horizons have not been traced completely around the nose of the fold owing to cover of later rocks, but structural mapping confirms the anticlinal structure. Along the main road from Macclesfield to Strathalbyn several minor anticlines and synclines have been seen. In this area there are several reversals of plunge, measurements varying between  $30^{\circ}$  S. and  $20^{\circ}$  N. No marker horizon of any value can be traced over the axis of this anticline. Numerous bands of andalusite-staurolite schist were found but they do not outcrop well and are only seen where gully erosion has stripped the soil cover. The Macclesfield Quartzite dies out on the western limb of the Strathalbyn Anticline. Sprigg and Wilson (*loc. cit.*) in their mapping of the Echunga Sheet show this quartzite cut off at the "Nairne Fault" but it can in fact be traced across the mapped position of the fault. A similar quartzite a few feet thick can be seen further south but it ceases to be a mappable horizon.

Grasso and McManus (1954) mapped the Callington Syncline west of Callington and extending north to Kanmantoo township. Their mapping showed complex folding and the complete absence of usable marker beds. In this area the structures are very well shown by air photographs. We have traced the synclinal axis further to the north to within 2 or 3 miles south of Harrogate where its location becomes more difficult. A big band of andalusite-staurolite schist which served as a marker horizon on the western limb of the syncline east and north-east of Dawesley could not be identified on the eastern limb. Moreover, as a consequence of the steep plunge ( $40-50^{\circ}$ ) and tight overturned folding all beds dip to the east and the two limbs are distinguished only by a change of  $20-30^{\circ}$  in strike. There is little doubt that the fold axis passes a short distance to the east of Harrogate and what is most probably the same synclinal structure is represented by two synclines and an anticline in the Nairne Pyritic Formation north-east of Hoods Hill (see Mannum Sheet — White and Thatcher, 1957).

East of Callington the Kanmantoo beds pass under alluvium of the Bremer Valley but further to the north, near "Lucernbrae", a series of tight folds — amplitude about 500 feet — indicate another anticline. This is, moreover, suggested by an outcrop of the Nairne Pyritic Horizons about  $3\frac{1}{2}$  miles north of "Lucernbrae". Here the pyritic beds pass into a minor syncline before being cut off by the Bremer Fault. Traced to the south they become involved in the tight folding and probably turn back northward before being lost under alluvium. This whole belt of folding merges into the Bremer Fault south-east of Harrogate.

In the vicinity of Shephard Hill the west limb of the Callington Syncline is bent into a subsidiary anticline and syncline. This structure dies away to the south but becomes more prominent in the Adelaide System beds to the north near Mt. Charles.

### THE BOUNDARY BETWEEN THE ADELAIDE SYSTEM AND THE KANMANTOO GROUP

When the Kanmantoo Group was first defined the boundary between the Adelaide System and the Kanmantoo in the eastern Mt. Lofty Ranges was considered to be a fault—named the Nairne Fault (Sprigg, *op. cit.*). The rocks inside the Macclesfield Syncline were considered to be Kanmantoo resting on the Macclesfield Marble and separated from the bulk of the Kanmantoo Group by the Nairne Fault. Much of the mapping was based on a supposed lithological difference between the Adelaide System and Kanmantoo rocks. The Adelaide System rocks are dominantly slaty and when metamorphosed form mica schists which do not make good outcrops. The Kanmantoo rocks are dominantly grey-wackes which form quartz-felspar-mica schists, and these form conspicuous slabby outcrops. On going eastward in the Mt. Lofty Ranges the change in outcrop pattern is quite marked and the "Nairne Fault" largely coincides with this line. From a point west of Shephard Hill to a point east of Macclesfield the "Nairne Fault" follows more or less closely the base of a thick series of cross-bedded micaceous quartzites which outcrop in the typical Kanmantoo style—although we would prefer to place them in the top of the Adelaide System (Marinoan Series).<sup>\*</sup> To the south of Macclesfield the Nairne Fault was believed to cut off the Macclesfield Quartzite. From this point the fault in its further passage southward lay between Kanmantoo rocks on either side.

The only area on the Echunga Sheet in which evidence for the Nairne Fault is to be looked for is thus immediately south of Macclesfield. We consider the Nairne Fault does not exist in this area for three reasons. Firstly, we have found an outcrop of the Nairne Pyritic Formation which can be traced for at least half a mile north of the supposed position of the fault and for about a mile south of the fault without any break in the outcrop, and then with breaks due to poor outcrop for another six miles south. Secondly, the axes of both the Macclesfield Syncline and the Strathalbyn Anticline can be traced undeviated across the line of the fault. Although this does not preclude a fault with a throw parallel to the axial plane of the folds it does preclude any fault which was required to do what the Nairne Fault was supposed to do. Lastly, the Macclesfield Quartzite which appears at first to be cut off by the Nairne Fault, does in fact cross the "fault" before dying out by change of facies. A thin, white quartzite band can be seen interbedded between quartz and felspar mica schists for a few hundred yards south of the "fault", and similar quartzites can be seen further to the south. On the other side of the Strathalbyn Anticline there is a cross-bedded micaceous quartzite in a similar position below the Nairne Pyritic Formation.

In 1956 Campana and Horwitz rejected the idea of the Nairne Fault and suggested that the boundary was an unconformity. They said that the relations

<sup>\*</sup> Owing to the fact that the Adelaide System beds on the eastern side of the Mt. Lofty Ranges are of markedly different sedimentary facies from those of the type localities on the western side, the division into Torrensian, Sturtian and Marinoan must be tentative only. In this paper we have followed the current usage of Sprigg *et al.* (1951, 1954). We have extended this usage by considering all the beds between the Sturtian and Kanmantoo to be Marinoan.

observed between the Adelaide System and the Kanmantoo Group were due to "erosion preceding the transgression of the Kanmantoo beds". They also inferred that the Adelaide System was folded before the erosion and subsequent transgression.

In the Macclesfield Syncline the Adelaide System beds pass up through the Macclesfield Quartzite, the Macclesfield Marble and Nairne Pyritic Formation to the greywackes of the Kanmantoo Group. There is no evidence at all of angular unconformity or any interruption in the sequence of sedimentation. Furthermore, it is apparent that the Adelaide System beds and the Kanmantoo Group have been folded as a single unit.

Our mapping has not revealed any evidence for a sedimentary break of any kind from Paris Creek to Harrogate. North of Harrogate White and Thutcher (1957) suggested conformity between the Nairne Pyritic Formation and the beds below. South of Paris Creek, however, Campana and Horwitz (1956) state that the Kanmantoo Group overlies successively older rocks until at Yankalilla it lies on the Archaean.

This is beyond the limits of our mapping, although we have seen the sections in several places. Mawson (1939) has recorded rocks which are slightly metamorphosed greywacke, similar in appearance to the rocks of the Kanmantoo Group, immediately above the quartzites of the Mt. Magnificent Ridge (base of Sturtian Series). Mawson records about 2500 feet of Adelaide System rocks below the topmost of the Mt. Magnificent Quartzites.

In the Grey Spur area further south Forbes (1957) records about 4000 feet of shale and quartzites overlain by greywackes and micaceous arkoses.

In the Mt. Magnificent area the quartzites of the Mt. Magnificent Ridge appear to be continuous with quartzites which Sprigg and Wilson (1954) place at the base of the Sturtian Series. At Grey Spur there is no evidence upon which to correlate the various rock types but the thicknesses measured suggest that the transition from the Adelaide System rocks to "Kanmantoo-type" rocks occurred at roughly the same time as at Mt. Magnificent.

It is clear that in the Mt. Magnificent area greywackes and impure arkoses appear to be conformably upon Adelaide System rocks of the Sturtian Series whereas in the Mt. Barker area the greywackes and impure arkoses do not appear until high in the Marinoan Series.

There are three possible explanations for the superposition of "Kanmantoo-type" rocks on the Sturtian Series at Mt. Magnificent.

1. Campana and Horwitz (1956) have suggested erosion of the upper part of the Sturtian and of the Marinoan and subsequent deposition of Kanmantoo. They also postulate folding of Adelaide System rocks during this interval.
2. Non-deposition during Upper Adelaidean time and subsequent deposition of Kanmantoo greywackes on to Sturtian beds.
3. Deposition of greywackes in the Mt. Magnificent area during Adelaidean time while normal Adelaide System sediments were being deposited further to the north.

Our mapping has shown that in the region between Harrogate and Paris Creek the Adelaide System and Kanmantoo rocks have folded as a single unit and we could find no evidence for an earlier period of folding involving only the Adelaide System. The Adelaide System beds are folded in the McIlarg Creek area south of Paris Creek but the Kanmantoo beds are folded also. Faulting and lack of outcrops have obscured the detail in this area, but no unequivocal evidence for an unconformity can be seen.



In the absence of fossils and marker horizons, it is impossible to decide the second and third hypothesis, but we feel that they explain the observed facts better than the hypothesis involving uplift, folding and erosion of the Adelaide System rocks as suggested by Campana and Horwitz.

### THE BASE OF THE KANMANTOO GROUP

The definition of the base of the Kanmantoo Group in our area rests upon the correlation of the Macclesfield Marble with the Delamere Marble and therefore with the Archeocyatha Marble. If we accept that correlation the base of the Kanmantoo would lie at some indefinite horizon just above the Marble. The Marble, however, does not outcrop well and has not been located east of Macclesfield. It is probably only of limited extent and lenses out before reaching the east side of the Macclesfield Syncline, although a small lens of a calc-silicate rock has been found below the Nairne Pyritic Formation in the eastern limb of the Macclesfield Syncline. From our mapping it is clear that the lowest member of the Nairne Pyritic Formation must be very close to the base of the Kanmantoo Group in the Macclesfield region. The lowest pyritic band lies about  $1200 \pm 200$  feet above the Macclesfield quartzite on the eastern limb, whilst the Macclesfield marble lies about 1000 feet above the quartzite on the western limb.

A further justification for making the Nairne Pyritic Formation the base of the Kanmantoo Group is that it obviously marks a boundary between two contrasting but conformable series of sediments. Below the pyritic beds are massive cross-bedded quartzites and arkoses, greywackes, shales, marbles and calc-silicates. Above the pyritic beds are a vast thickness of very fine-grained greywackes and siltstones with minor shale bands. We do not consider that the pyritic beds mark a break in sedimentation.

### CONCLUSIONS

This paper presents the results of mapping of the Kanmantoo Group rocks in the area around Kanmantoo township. It shows that these rocks rest conformably above the rocks mapped as Adelaide System. The mapping suggests that the Macclesfield marble and quartzite are two lenticular beds of limited extent and quite useless as marker horizons. The correlation of the quartzite of Mt. Barker Summit with the Macclesfield quartzite, as suggested by the mapping of the Echunga Sheet, is incorrect. It is more probable that the Mt. Barker quartzite represents a lens of pure quartzite in a dominantly arkosic and greywacke series.

The contact between the Adelaide System and the Kanmantoo Group seems to be one of definition on the Echunga Sheet. The earlier concept of a faulted contact is disproven by the mapping of marker horizons and structural features across the line of the supposed fault. The later suggestion of a transgression of the Kanmantoo Group over the Adelaide System can neither be proved nor disproved in this area. In the sequence of sediments we have examined there is certainly no reason to believe that a break in sedimentation has occurred.

We propose that the base of the Nairne Pyritic Horizon be defined as the base of the Kanmantoo Group in this area, and until further evidence can be found, the beds immediately below the Nairne Pyritic Formation be considered as Marinoan. The base of the Marinoan has not been considered.

### ACKNOWLEDGMENTS

Expenses in connection with this work were defrayed from the University Research Grant. We are indebted to Mr. R. Offler for assistance with field work

and to Mr. B. P. Webb and Mr. B. P. Thomson of the Geological Survey for helpful discussions.

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# NOTES ON WESTERN AUSTRALIAN FISHES, NO. 1

BY *T. D. SCOTT*

## Summary

Seven new species from North Western Australia are described and figured. New localities and ranges of distribution are given for seventeen Western Australian fishes. Sixteen further species are recorded as new records for that State, and eight species, one of which is figured, are listed as new records for Australia. *Polynemus specularis* De Vis is considered to be a synonym of *Polynemus multirudiutus* Gunther.

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[read 12 June 1958]

### SUMMARY

Seven new species from North Western Australia are described and figured. New localities and ranges of distribution are given for seventeen Western Australian fishes. Sixteen further species are recorded as new records for that State, and eight species, one of which is figured, are listed as new records for Australia. *Polynemus specularis* De Vis is considered to be a synonym of *Polynemus multiradiatus* Gunther.

### INTRODUCTION

During the past five years the Underwater Spearfishermen's Association of Western Australia has sent to the South Australian Museum for identification, a collection of about 500 onshore and reef-living fishes from that State. These fishes, collected by means of the spear-gun, or multi-pronged hand spear, were preserved in formalin, packed in 4-gallon collecting drums, and forwarded to the Museum. The accompanying notes on the specimens provided useful information as to the distribution, abundance and habitats of these fishes. In many cases, coloured photographs were taken at the time of capture of the specimens, and these have provided useful records of life colouration.

This is the first of a series of papers dealing with the fishes of Western Australia; I wish to express my thanks to the Underwater Spearfishermen's Association of Western Australia and in particular to Mr. F. Barrett-Lennard for his valuable assistance in the collecting of many of these specimens, and for the most useful notes and colour photographs which he has placed at my disposal.

#### Family SYNODONTIDAE

Genus *SAURIDA* Cuv. and Val., 1849

*Saurida tumbil* (Bloch)

*Salmo tumbil* Bloch, 1795, Nat. Ausl. Fische, 9, p. 112.

Two specimens measuring 155 mm. and 170 mm. total length were taken at Point Samson, August, 1957, and Exmouth Gulf, November, 1954, respectively. Add area 5 to Whitley's (1948, p. 13) distribution of this species in Western Australia.

#### Family MUGILIDAE

Genus *LIZA* Jordan and Swain, 1884

*Liza vaigiensis* (Quoy and Gaimard)

*Mugil vaigiensis* Quoy and Gaimard, 1824, Voy. Uranie Physic., p. 337, pl. 59, fig. 2.

A small specimen measuring 108 mm. total length was taken at Point Samson, December, 1957. Add area 5 to Whitley's (1948, p. 17) distribution of this species in Western Australia.

## Family POLYNEMIDAE

Genus POLYNEMUS Linnaeus, 1758

*Polynemus multiradiatus* Gunther*Polynemus multiradiatus* Gunther, 1860, Cat. Fish. Brit. Mus., 2, p. 324.*Polynemus specularis* De Vis, 1883, Proc. Linn. Soc. N.S.W., 8 (2), p. 285.

A small specimen measuring 145 mm. total length was taken at Point Samson, August, 1957. This species was first recorded from Western Australia by Whitley (1952-53, p. 29) as *Polydactylus specularis* (De Vis). The above synonymy of *P. specularis* De Vis is suggested.

My thanks to Mr. T. C. Marshall for material from the collection of the Department of Harbours and Marine, Queensland.

## Family EPINEPHELIDAE

Genus EPINEPHELIUS Bloch, 1793

*Epinephelus homosinensis* Whitley*Epinephelus homosinensis* Whitley, 1944, Austr. Zool., 10 (3), p. 267.

A specimen measuring 315 mm. total length was taken at Point Samson, August, 1957. Previously recorded only from the Geraldton-Abrohos region, Western Australia, where it is known as the "Chinaman Cod". Add areas 4 and 5 to Whitley's (1948, p. 18) distribution of this species in Western Australia.

Genus PLECTROPOMUS Cuvier, 1817

*Plectropomus maculatus* (Bloch)*Bodianus maculatus* Bloch, 1790, Nat. Ausl. Fische, 4, p. 48.

A specimen measuring 258 mm. total length was taken at Point Samson, August, 1955. Add area 5 to Whitley's (1948, p. 18) distribution of this species in Western Australia.

## Family PSEUDOCROMIDAE

## KEY TO THE PSEUDOCROMIDAE OF WESTERN AUSTRALIA

- |   |       |  |   |
|---|-------|--|---|
| 1. Dorsal spines more than 4  | ..... | <i>Stigmatonotus australis</i>             |   |
| Dorsal spines less than 4   | ..... |  | 2 |
| 2. Dorsal spines 2, palatines toothless   | ..... |  | 3 |
| Dorsal spines 3, palatines with teeth   | ..... |  | 4 |
| 3. Ventral fins close together; a large pink spot on side of body                 |       | <i>Dampiera ignita</i> sp. nov.            |   |
| Ventrals separated by a scaly process; body with 16 to 17 dark longitudinal lines | ..... | <i>Dampiera lineata</i>                    |   |
| 4. All dorsal and anal rays branched  | ..... | <i>Leptochromis tapeinosoma wilsoni</i>    |   |
| Some anterior dorsal rays simple, the posterior rays branched                     | ..... |  | 5 |
| 5. Teeth of vomer and palatines in 4 or 5 rows; lateral line scales 38 + 6-7      | ..... | <i>Pseudochromis (Assiculus) punctatus</i> |   |
| Teeth of vomer and palatines in a single row; lateral line scales 30 + 8-10       | ..... | <i>Pseudochromis (Devissina) fuscus</i>    |   |

Genus DAMPIERIA Castelnau, 1875

*Dampiera lineata* Castelnau*Dampiera lineata* Castelnau, 1875, Res. Fish. Austr., p. 30.

A specimen measuring 166 mm. total length was taken at Point Samson, August, 1955. Add area 5 to Whitley's (1948, p. 18) distribution of this species in Western Australia.

*Dampieria ignita* sp. nov.

D.ii.25. A.i.17. A.iii.14. V.i.5. C.17. Br.6.

Lat. line 57+21-23.

Length of head 48 mm. (4.1), greatest depth of body 45 (4.4), greatest width of body 23 (8.6) in the total length 198 mm. Height of head 1.2 in its length. Eye 10 (1.3) in the snout, and 0.7 in the convex interorbital space. Snout 13 (3.7) in the head.

Cleft of mouth very oblique, curved downward posteriorly, almost reaching the ventral profile, terminating below the anterior border of the eye. Lower jaw longer than upper. Teeth in upper jaw in several series, the outer row

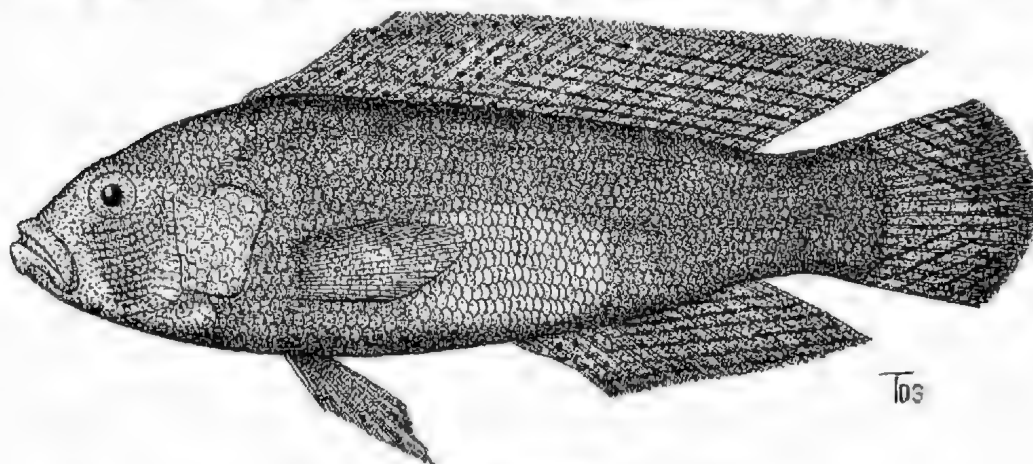


Fig. 1.—*Dampieria ignita* sp. nov. ( $\times \frac{1}{2}$ ).

enlarged. Two pairs of canines in front, the outer pair larger, slightly curved. Teeth in lower jaw uniserial laterally, 2 pairs of enlarged canines in front, of equal size, a patch of smaller teeth behind each pair. Palatines without teeth. Vomer with a single row of small conical teeth.

Ten rows of cycloid scales on the cheek, the upper scales the largest. Operculum with six to seven rows of larger scales. Preoperculum entire, operculum unarmed.

Head scales beginning between eyes, small and cycloid. Rest of body covered with ctenoid scales of moderate size, forming a low basal sheath on the vertical fin. Lateral line interrupted below the twentieth dorsal ray, the upper part separated from the lower by five rows of scales. Lateral line scales with a short simple tube.

Dorsal long, originating above hindborder of operculum, consisting of 2 weak spines and 25 rays, the posterior rays prolonged. Anal with 3 stronger spines, the third the longest, but not equal to the eye diameter. Ventrals close together, the third ray produced. Pectoral of moderate size, its length 1.5 in the head. Caudal fin rounded.

*Colour in alcohol.*—Body coloured a dark brown, with some traces of darker longitudinal bands as in *lineata*. A large whitish oval patch (which is pink in life) on the sides, behind the pectoral fin, extending downwards to the ventral profile, upward to the fourth row of scales below the lateral line, and backward almost to the beginning of the lower lateral line. Dorsal and anal fins with dark spots, anteriorly, parallel dark bands posteriorly, these bands extending on to the caudal fin.

Described from a specimen 198 mm. total length, taken Sharks Bay, May, 1954. Type in South Australian Museum, Reg. No. F2997. Further specimens measuring 119 mm., 130 mm., and 156 mm. total length were taken at Point Samson, December, 1957.

*Affinities*.—Differs from *D. lineata* in body proportions, in colouration, in the more posterior insertion of the anal fin, and in the separation of the ventrals. In *D. ignita*, the ventrals are very close together; *D. lineata* has the ventrals more widely separated, and there is a scaly process between their bases.

#### Family TERAPONTIDAE

Genus EUTHERAPON Fowler, 1904

*Eutherapon theraps* (Cuv. and Val.)

*Therapon theraps* Cuvier and Valenciennes, 1829, Hist. Nat. Poiss., 3, p. 129, pl. 53.

A specimen measuring 138 mm. total length was taken at Point Samson, August, 1955. This species was first recorded from Western Australia as *Therapon rubriculus* Richardson, 1842, and Whitley (1948, p. 19) does not indicate its distribution in Western Australia, except "N.W. Australia". Add area 5 to Whitley's distribution of this species in Western Australia.

#### Family CARANGIDAE

Genus CARANX Lacepede, 1802

*Caranx bucculentus* Alleyne and Macleay

*Caranx bucculentus* Alleyne and Macleay, 1877, Proc. Linn. Soc. N.S. Wales, 1 (4), p. 326, pl. 11, fig. 1.

A specimen measuring 124 mm. total length was taken at Broome, June, 1955. Dorsal fin i,viii,i,19. Anal fin ii,i,16. The straight part of the lateral line commences below the 6th dorsal spine, and bears 37 scutes. The five broad dark cross-bars from the back to the middle of the sides, as noticed by McCulloch in a specimen 123 mm. in length, are apparent.

A second record of this species for Western Australia.

Genus ELAGATIS Bennett, 1835

*Elagatis bipinnulatus* (Quoy and Gaimard)

*Seriola bipinnulata* Quoy and Gaimard, 1825, Voy. Uranie Physic. (Zool.), 1, p. 363, pl. 61, fig. 3.

A large specimen measuring 650 mm. total length was taken at Point Samson, August, 1957. A second record for Western Australia. Add area 5 to Whitley's (1948, p. 20) distribution of this species in Western Australia.

In this specimen, the two detached anal spines characteristic of the Carangidae, have become obsolete with age.

#### Family LUTIANIDAE

Subfamily LUTIANINAE

Genus LUTIANUS Bloch, 1790

*Lutianus russelli* (Bleeker)

*Mesoprion russelli* Bleeker, 1849, Verh. Bat. Gen., 22, Perc., p. 41.

A small specimen measuring 160 mm. total length was taken at Exmouth Gulf, November, 1954. Above the lateral line there is a series of narrow bands, passing obliquely upwards and backwards to the dorsal profile. Below the lateral line, the specimen bears three horizontal wider bands, parallel to the axis of the body. The black, oval, lateral blotch, measuring 13 mm. by 9 mm., is

almost entirely above the lateral line, and is situated below the junction of the posterior dorsal spines and anterior rays.

A new record for Western Australia.

***Lutianus chrysotaenia* (Bleeker)**

*Mesoprion chrysotaenia* Bleeker, 1851, Nat. Tijdsch. Ned. Indie, 2, p. 170.

A specimen was taken at Point Samson, August, 1955. Add area 5 to Whitley's (1948, p. 21) distribution of this species in Western Australia.

***Lutianus vitta* (Quoy and Gaimard)**

*Serranus vitta* Quoy and Gaimard, 1824, Voy. Uranie Physic. (Zool.), p. 315, pl. 58, fig. 3.

A small specimen measuring 125 mm. total length was taken at Point Samson, August, 1957. Add area 5 to Whitley's (1948, p. 21) distribution of this species in Western Australia.

**Sub-family NEMIPTERINAE**

**Genus NEMIPTERUS Swainson, 1839**

**KEY TO THE AUSTRALIAN SPECIES OF NEMIPTERUS**

- |   |                        |                                |
|---|------------------------|--------------------------------|
| 1. Lower jaw with canine teeth                                      | .....                  | 2                              |
| Lower jaw without canines   | .....                  | 4                              |
| 2. Eleven rows of scales below lateral line; body with yellow bands |                        |                                |
|   | <i>N. laeniopterus</i> |                                |
| Fourteen rows of scales below lateral line; body without bands      | .....                  | 3                              |
| 3. Lower jaw with six canines; colour uniform                       | .....                  | <i>N. robustus</i>             |
| Lower jaw with eight canines; colour brown above, silvery below     |                        |                                |
|   | <i>N. sundanensis</i>  |                                |
| 4. Posterior dorsal spines longest                                  | .....                  | <i>N. theodorei</i>            |
| Median dorsal spines longest  | .....                  | 5                              |
| 5. Upper caudal lobe greatly produced                               | .....                  | <i>N. auriflum</i>             |
| Upper caudal lobe not produced                                      | .....                  | 6                              |
| 6. Upper jaw with three pairs of canines                            | .....                  | <i>N. upeneoides</i>           |
| Upper jaw with one pair of canines                                  | .....                  | <i>N. samsonensis</i> sp. nov. |

***Nemipterus samsonensis* sp. nov.**

D.x,9. P.16. A.iii,7. V.i,5. C.18. Br.6.

Lat. line 49-50. Lat. trans. 3:11.

Length of head 44 mm. (4.5), greatest depth of body 51 (4.0), greatest width of body 25 (8.0) in the total length 200 mm. Height of head 1.1 in its length. Eye 13 (1.2) in the snout and 0.8 in the flat interorbital space. Snout 15 (2.9) in the head.

Body elongated, not very deep, rather compressed. Mouth of moderate size, horizontal, maxillary reaching to posterior nostril. Jaws equal.

Bands of small pointed teeth in both jaws, narrowing laterally, with the outer row enlarged. One pair of moderate canines in upper jaw, lower jaw without canines. Palato without teeth. Lips rather thick.

Preoperculum rectangular, rounded at angle, smooth behind. Suborbital rather deep, more than half vertical diameter of eye. Posterior angle very obtuse, the hindborder a straight line which when produced above reaches the origin of the dorsal fin. Naked limb of preoperculum about half depth of scaly part.

Body covered with moderate ctenoid scales. Nape, operculum and cheek scaly, rest of head naked. Three oblique rows of large cycloid scales on cheek

below suborbital, leaving a naked limb below on preoperculum. Body scales continued to end of caudal fin. Lateral line complete, not sharply bent, consisting of unbranched oblique tubes. Ventral fins with an axillary process.

Dorsal fin consisting of ten slender spines, the middle spines the longest. Membrane between dorsal spines slightly emarginate. Posterior spines shorter

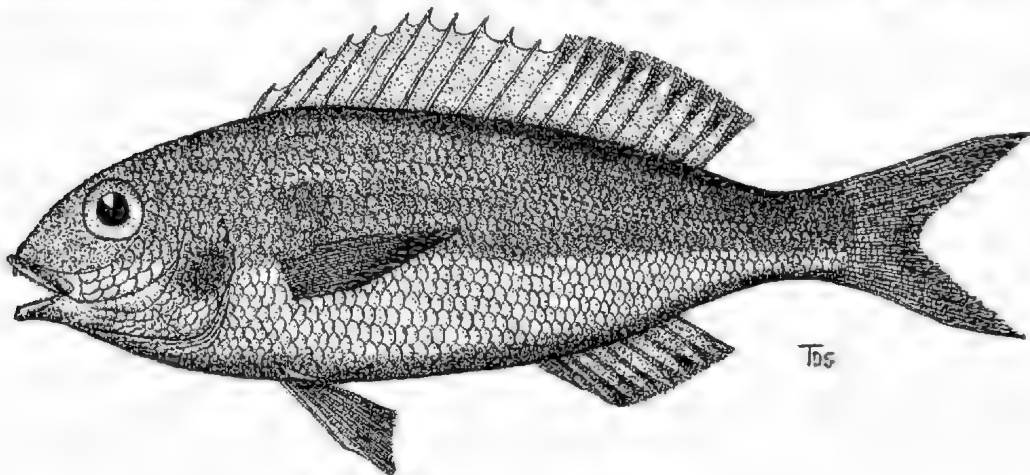


Fig. 2.—*Nemipterus samsonensis* sp. nov. ( $\times \frac{2}{3}$ ).

than first rays. Pectorals long, almost equal to head. Ventrals shorter, not reaching to vent. Anal spines slender, the first very short, the third longest, equal in length to diameter of eye. Anal rays longer than third spine. Caudal fin deeply forked, consisting of eighteen principal rays. Pseudobranchiae present.

*Colours in life*.—Body and head pinkish above, silvery below. A large dark patch on the operculum. A round dark patch on body immediately behind head and below lateral line. Flus pinkish, without any markings.

Described from a specimen 200 mm. total length, taken Point Samson, November, 1954. Type in South Australian Museum, Reg. No. F2966.

Genus *SCOLOPSIS* Cuvier, 1817

*Scolopsis bilineatus* (Bloch)

*Anthias bilineatus* Bloch, 1793, Nat. Ausl. Fische 7, p. 3.

Two specimens measuring 195 mm. and 96 mm. total length were taken at Point Samson, December, 1957.

The adult and juvenile specimens exhibit a considerable difference in coloration and pattern. The colours in alcohol are as follows:—

Adult, greenish above, breast silvery, sides yellow. Two greyish-silver stripes on sides, one arising immediately above the eye, the second from the upper part of the eye, passing backwards and upwards towards the dorsal profile, but not reaching it. A third much broader stripe arises below the eye, and passes upwards obliquely to end below the last dorsal spine and the first soft ray. It is bordered above and below by a dark brown stripe. A black patch covers the membrane and distal parts of the last two dorsal spines and first four rays. Anal spines, first two anal rays and the membrane between them black. Other fins hyaline.

In the juvenile, in addition to the three longitudinal stripes, there arises in the interorbital space a narrow stripe which passes back to the beginning of the dorsal fin. The three inferior stripes are all parallel and of approximately equal



width, passing back obliquely to the dorsal profile, the interspaces coloured dark brown. A black patch on the posterior part of the dorsal fin, as in adult. In addition, there is a large black ocellus on the membrane between the first three dorsal spines. Anal fin black at the tip of the last spine and first two rays. Other fins hyaline, without any markings.

A new record of this species for Australia.

#### Family GERRIDAE

Genus *Gerres* Quoy and Gaimard, 1824

#### *Gerres australis* Castelnau

*Gerres australis* Castelnau, 1875, Res. Fish. Austr. (Vict. Offic. Rec. Philad. Exhib.), p. 43.

A specimen measuring 110 mm. total length was taken at Point Samson, August, 1955.

Upper parts dark metallic blue, under parts silvery, the two colours sharply defined by a line passing above the orbit and through the middle of the caudal peduncle. There are 7 to 8 thin dark vertical bars on the sides, which become more obvious in alcohol.

Add area 5 to Whitley's (1948, p. 21) distribution of this species in Western Australia.

#### Family POMADASIDAE

Genus *Plectorhynchus* Lacépède, 1802

#### *Plectorhynchus chaetodonoides* Lacépède

*Plectorhynchus chaetodonoides* Lacépède, 1802, Hist. Nat. Poiss., 3, p. 134.

A specimen measuring 490 mm. total length was taken at Point Samson, August, 1955. An adult specimen in which the first and second dorsal fins and caudal fin are densely covered with large brown spots. Back, sides and upper caudal peduncle similarly spotted. Pectorals, anal and ventrals a uniform dark brown.

Weber and De Beaufort (1936, p. 414) record the maximum size of this species as 450 mm., but the specimen from Point Samson measured 490 mm., total length.

A new record of this species for Australia.

#### *Plectorhynchus ordinalis* sp. nov.

D.xii,16. P.17. A.iii,7. V.i,5. C.17. Br.7.

Lat. line 58-60. Lat. trans. 23:26-30.

Length of head 50 mm. (4.0), greatest depth of body 66 (3.0), greatest width of body 21 (9.4) in the total length 198 mm. Height of head 1.0 in its length. Eye 12 (1.7) in the snout and 1.0 in the convex interorbital space. Snout 20 (2.5) in the head.

Body rather deep, somewhat compressed. Mouth small, slightly oblique, scarcely protractile. Maxillary reaching to below posterior nostril. Lips thick. Both jaws with several rows of small conical teeth, the outer row in both jaws enlarged. No canines. Palatines and vomer toothless.

Preoperculum rectangular, serrated posteriorly. Body and head covered with small ctenoid scales, with the exception of the snout, lips and chin. Interorbital scales extending forward to anterior nostril. Soft dorsal and anal fins with a scaly sheath. Ventral fins with an axillary process. A row of six pores on the chin, behind lower lip. Lateral line complete, gently curved throughout its length, each scale with a simple oblique tube. Body scales above lateral line much smaller than those below.

Dorsal fin with 12 strong spines, the third and fourth spines the longest, length 18 mm. Spines decreasing gently in length posteriorly, the last spine not much shorter than the first ray. Pectorals of moderate length, equal to length of ventrals. Ventral fins pointed, reaching to vent. First anal spine minute, second spine the longest, length equal to greatest body width. Caudal fin truncate.

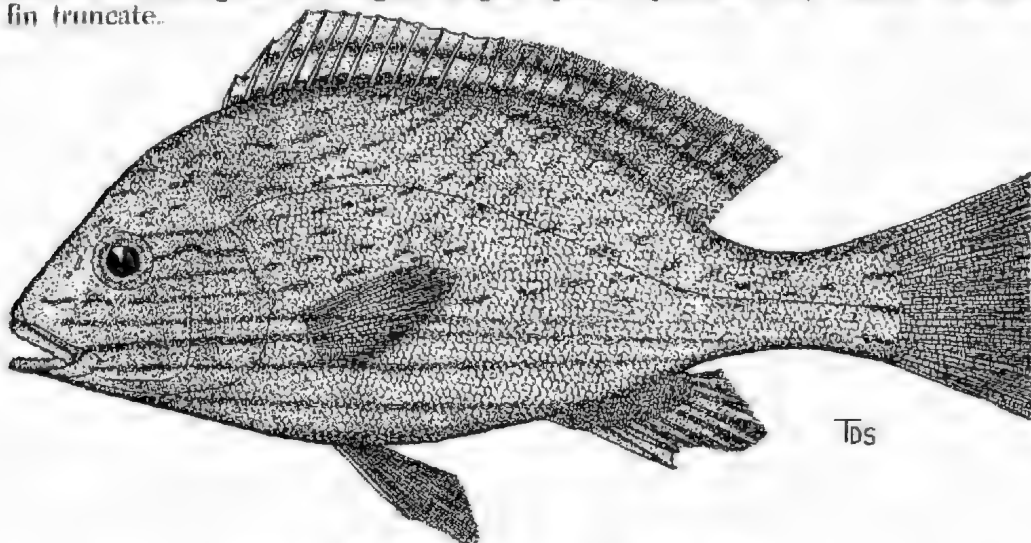


Fig. 3.—*Plectorhynchus ordinalis* sp. nov. ( $\times \frac{1}{2}$ ).

**Colours in life.**—Body coloured blue-grey above, white below. Eight to nine bright yellow longitudinal bands on the head, extending on to the body. These bands remain distinct on the lower half of the body, but become broken up into a series of dots and short bands on the upper half. Two distinct rows of similarly coloured spots along the entire length of the dorsal fin. All other fins coloured a transparent light yellow.

Described from a specimen 198 mm. total length, taken Sharks Bay, May, 1954. Type in South Australian Museum, Reg. No. F3006.

**Affinities.**—Similar to *chrysotaenia* Bleeker in body proportions and colouration, but differs in the dorsal fin counts (12 spines and 16 rays, compared with 13 spines and 19-20 rays in *chrysotaenia*), and in scale counts.

#### Family MULLIDAE

Genus *BARBUPENEUS* Whitley, 1931

*Barbupeneus signatus* (Gunther)

*Upeneus signatus* Gunther, 1867, Ann. Mag. Nat. Hist. (3), 20, p. 59.

Two specimens measuring 180 mm. and 211 mm. total length were taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

#### Family LETHRINIDAE

Genus *LETHRINICHTHYS* Jordan and Thompson, 1912

*Lethrinichthys nematacanthus* (Bleeker)

*Lethrinus nematacanthus* Bleeker, 1854, Nat. Tijdschr. Ned. Ind., 6, p. 403.

A small specimen measuring 174 mm. total length was taken at Point Samson, August, 1957. Add area 5 to Whitley's (1948, p. 22) distribution of this species in Western Australia.

*Lethrinichthys*, erected as a sub-genus by Jordan and Thompson, has been regarded by previous authors (McCulloch, 1929; Weber and de Beaufort, 1936) as a synonym of *Lethrinus*. However, Whitley (loc. cit.) has raised the sub-genus to generic status, the two genera being separated by the character of the lateral teeth.

#### Family SPARIDAE

##### Genus MYLIO Lacepède, 1802

##### *Mylio latus* (Houttuyn)

*Sparus latus* Houttuyn, 1782, *Haarlem, Verh. Holl. Maatsch. Wet.*, 20 (2), p. 322.

D.xi,12. P.15. A.iii,9. V.i,5. C.17.

Lat. line 50. Lat. trans. 4:11.

A young specimen measuring 165 mm. standard length was taken at Point Samson, August, 1955.

Six curved incisors in each jaw. Upper jaw with 4 rows of molars on each side, the outer row considerably flattened laterally. Lower jaw with 3 rows of molars, the outer series not much flattened. A small dark blotch at the origin of the lateral line, and a dark hind border to the operculum. No black spot in axil of pectoral. Dorsal fins dusky, ventrals and anal without markings. A narrow dark border to the caudal fin.

#### Family PEMPHERIDAE

##### Genus PEMPHERIS Cuvier, 1829

##### *Pempheris compressa* (Shaw)

*Sparus compressa* White, 1790, *Voy. N.S. Wales*, p. 267, pl. 12, fig. 2. Ex Shaw MS.

Two specimens measuring 114 mm. and 131 mm. total length were taken at Point Samson, December, 1957. This species was recorded from Western Australia by McCulloch (1929, p. 234), but was omitted from Whitley's (1948) list of the fishes of Western Australia.

#### Family CHAETODONTIDAE

##### Genus MEGAPROTODON Guichenot, 1848

##### *Megaprotodon strigangulus* (Gmelin)

*Chaetodon strigangulus* Gmelin, 1788, *Syst. Nat.*, ed. 13, p. 1269.

Two specimens measuring 145 mm. and 147 mm. total length were taken at Point Samson, December, 1957.

A new record of this species for Australia.

##### Genus ANISOCHAETODON Klunzinger, 1884

##### *Anisochaetodon lineolatus* (Cuv. and Val.)

*Chaetodon lineolatus* Cuvier and Valenciennes, 1831, *Hist. Nat. Poiss.*, 7, p. 40.

A small specimen measuring 145 mm. total length was taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

##### Genus CHAETODON Linnaeus, 1758

##### *Chaetodon lunula* (Lacepède)

*Pomacentrus lunula* Lacepède, 1802, *Hist. Nat. Poiss.*, 4, p. 507.

Two specimens measuring 185 mm. and 190 mm. total length were taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

Genus *EUXIPHPOPS* Fraser-Brunner, 1934*Euxiphipops sexstriatus* (Cuv. and Val.)*Holacanthus sexstriatus* Cuv. and Val., 1831, Hist. Nat. Poiss., 7, p. 194.

Previous Australasian records: Cape Grenville, Queensland (Alleyne and Macleay, 1877, p. 277); Port Darwin, N.T. (Macleay, 1878, p. 352); Port Moresby (Macleay, 1883, p. 244); Darnley Is. (Ogilby, 1915, p. 105); Low Is., Queensland (Whitley, 1932, p. 288).

A specimen measuring 265 mm. total length was taken at Point Samson, August, 1955.

A new record for W.A., and the most southerly record for this species to date.

Genus *HENIOCHUS* Cuvier, 1817*Heniochus acuminatus* (Linnaeus)*Chaetodon acuminatus* Linnaeus, 1758, Syst. Nat., 10, p. 272.

Previous Australasian records: Port Darwin and Port Essington (Macleay, 1881, p. 94); Hood Bay, New Guinea (Macleay, 1884, p. 263); Cape Byron Light, N.S. Wales (McCulloch, 1916, p. 193); northern N.S. Wales (McCulloch, 1922, p. 91).

A specimen measuring 155 mm. total length was taken at Sharks Bay, May, 1954.

A new record for Western Australia.

Genus *CHAETODON* Linnaeus, 1758*Chaetodon aureofasciatus* Macleay*Chaetodon aureofasciatus* Macleay, 1878, Proc. Linn. Soc. N.S. Wales, 2 (4), p. 351, pl. 8, fig. 3.

D.xi,23. A.iii,19.

Lat. line 35-36. Lat. trans 13 : 23-24.

Length of head 28 mm. (4.2), greatest depth of body 88 (1.4), greatest width of body 15 (7.9) in the total length 118 mm. Height of head 0.4 in its length. Eye 9 (0.8) in the snout and 1.2 in the convex interorbital space. Snout 7 (4.0) in the head. Depth of body equal to standard body length. Depth of caudal peduncle 11, equal to interorbital space.

A specimen measuring 118 mm. total length was taken at Point Samson, August, 1955.

This specimen has the two bands across the caudal peduncle as seen by Macleay in the juveniles of this species.

A new record for Western Australia.

Family *AMPHACANTHIDAE*Genus *AMPHACANTHUS* Bloch and Schneider, 1801*Amphacanthus vermiculatus* Cuv. and Val.*Amphacanthus vermiculatus* Cuvier and Valenciennes, 1835, Hist. Nat. Poiss., 10, p. 126.

A specimen measuring 293 mm. total length was taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

*Amphacanthus chrysopilos* Bleeker*Amphacanthus chrysopilos* Bleeker, 1852, Nat. Tijdschr. Ned. Indie, 3, p. 66.

A specimen measuring 250 mm. in length (to caudal fork) was taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

*Amphacanthus doliatus* Cuv. and Val.*Amphacanthus doliatus* Cuvier and Valenciennes, 1835, Hist. Nat. Poiss., 10, p. 132.

A specimen measuring 184 mm. in length (to caudal fork) was taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

## Family TEUTHIDAE

Genus TEUTHIS Linnaeus, 1766

*Teuthis glaucopareius* (Cuvier)*Acanthurus glaucopareius* Cuvier, 1829, Regne Anim. ed. 2 (2), p. 224.

A specimen measuring 152 mm. total length was taken at Point Samson, December, 1957.

A new record of this species for Australia.

*Teuthis triostegus* (Linnaeus)*Chaetodon triostegus* Linnaeus, 1758, Syst. Nat., ed. 10, p. 274.

A specimen measuring 185 mm. total length was taken at Point Samson, December, 1957.

Add area 5 to Whitley's (1948, p. 24) distribution of this species in Western Australia.

## Family ACANTHURIDAE

Genus NASO Lacepede, 1802

*Naso unicornis* (Forsk.)*Chaetodon unicornis* Forskal, 1775, Descr. Anim., p. 63.

A specimen measuring 335 mm. total length (excluding caudal filaments) was taken at Point Samson, December, 1957.

Body coloured a uniform dark brown. Dorsal fin with narrow, dark longitudinal bands. The horn on the forehead is very well developed in this specimen.

A new record of this species for Western Australia.

*Naso lituratus* (Bloch and Schneider)*Acanthurus lituratus* Bloch and Schneider, 1801, Syst. Ichth., p. 216.

A specimen measuring 256 mm. total length (excluding caudal filaments) was taken at Point Samson, December, 1957.

Body coloured a uniform dark grey. The two bony spines on each side of the caudal peduncle surrounded by a yellow oval spot. A thin yellow band passing forwards below the eye and thence downwards to behind the angle of the mouth. Lower lip light coloured. Dorsal fin black, bordered by a broad cream band, followed by very thin black band.

Anal fin bordered by a similar black band, otherwise dark grey. Pectorals black, ventrals grey. Caudal bordered by a broad white band.

A new record of this species for Australia.

Genus ACANTHURUS Forskal, 1775

*Acanthurus doreensis* Cuv. and Val.*Acanthurus doreensis* Cuvier and Valenciennes, 1835, Hist. Nat. Poiss., 10, p. 220.

A specimen measuring 220 mm. (length to caudal fork) was taken at Point Samson, December, 1957.

Colours: Body, dorsal, ventral and anal fins a uniform dark brown. Pectoral fin brownish at base, its upper distal part yellow. A narrow white posterior border to the caudal fin.

A new record of this species for Australia.

## Family ZANCLIDAE

Genus ZANCLUS Cuv. and Val., 1831

*Zanclus canescens* (Linnaeus)*Chaetodon canescens* Linnaeus, 1758, Syst. Nat., ed. 10, p. 272.

Two juvenile specimens measuring 119 mm. and 140 mm. total length were taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

## Family POMACENTRIDAE

Genus GLYPHISODON Lacepede, 1802

*Glyphisodon coelestinus* Cuv. & Val.*Glyphisodon coelestinus* Cuvier and Valenciennes, 1830, Hist. Nat. Poiss., 5, p. 464, pl. 135.

A specimen measuring 115 mm. total length was taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

Genus CHROMIS Cuvier, 1815

*Chromis cinerascens* (Cuv. and Val.)*Heliases cinerascens* Cuvier and Valenciennes, 1830, Hist. Nat. Poiss., 5, p. 495.

Two specimens measuring 104 mm. and 115 mm. total length were taken at Point Samson, December, 1957.

A new record of this species for Australia.

## Family CORIDAE

Genus CHEILIO Lacepede, 1802

*Cheilio incrimis* (Forsk.)*Labrus incrimis* Forskal, 1775, Deser. Anim., p. 34.

A specimen measuring 202 mm. total length was taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

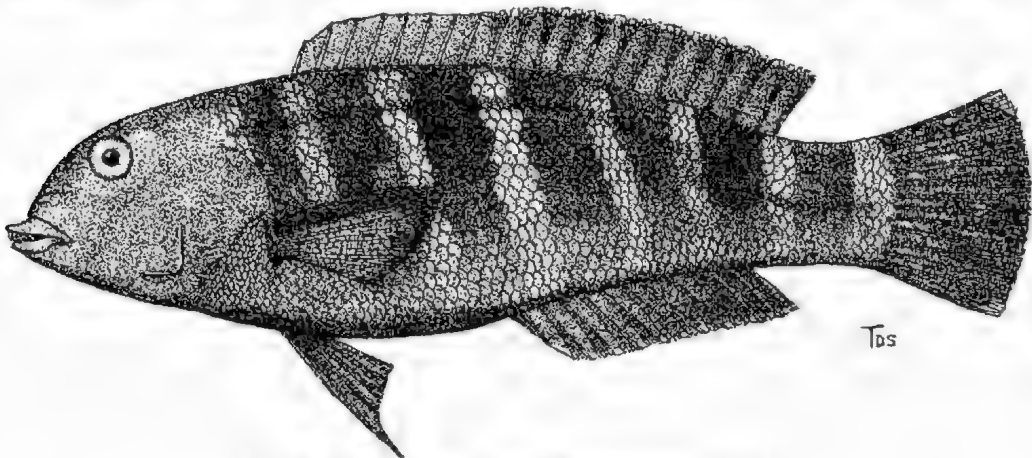
Genus THALASSOMA Swainson, 1839

*Thalassoma septemfasciata* sp. nov.

D.viii,13. P.15. A.iii,11. V.i,5. C.14.

Lat. line 45-46. Lat. trans. 4:16.

Length of head 56 mm. (3.8), greatest depth of body 54 (3.7), greatest width of body 22 (9.7) in the total length 214 mm. Height of head 1.3 in its

Fig. 4.—*Thalassoma septemfasciata* sp. nov. ( $\times \frac{2}{3}$ ).

length. Eye 10 (2.1) in the snout and 1.3 in the convex interorbital space. Snout 13 (4.3) in the head.

Mouth small, horizontal, not reaching anterior border of eye. Lips very thick. Premaxilla only slightly protractile. Teeth pointed, in a single series in

each jaw, decreasing in size posteriorly. Two moderate canines in each jaw. Head naked, with the exception of a few scales on the upper part of the opercle. About ten small scales before the dorsal.

Body covered with moderate sized cycloid scales, which form a basal sheath on the dorsal and anal fins. Lateral line following the dorsal profile for the greater part of its length, sharply deflected below the tenth dorsal ray. Dorsal spines short and slender, the first very short, the last spine the longest, but not as long as the rays. Origin of anal slightly behind first dorsal ray. First anal spine very small, third longest, equal to diameter of eye. Pectorals equal to head without snout, the second and third rays the longest, decreasing uniformly, the shortest ray one-fourth of the longest. First ray of ventrals produced, reaching anus. Caudal rounded.

*Colour in life.*—Body colour light blue, with seven darker blue bands, the width of the bands much greater than the interspaces. The first band arises in front of the dorsal fin, and runs to the base of the pectoral. The second and third arise below the spinous dorsal, and pass obliquely across the body. The fourth to sixth arise on the middle of the soft dorsal membrane and run obliquely to the base of the anal. The seventh crosses the broad caudal peduncle. Caudal fin bluish, with light spots. Dorsal fin uniform bluish, with a narrow light border to the soft part. Anal blue with light streaks, a broad light border the entire length of the fin. The upper five rays of the pectoral dark blue, the lower part lightish, a broad dark band covering the distal part of the fin above, becoming obscure below. Head without any distinct markings, dark bluish.

Described from a specimen 214 mm. total length, taken Sharks Bay, May, 1954. Type in South Australian Museum, Reg. No. F2984.

*Material examined.*—Two specimens, measuring 202 and 214 mm. total length.

*Affinities.*—Similar to *T. hardwicki* (Bennett) in body proportions and banding on body, but differing in colouration, absence of bands on head and much greater number of scales in lateral line (45-46, compared with 27-28 in *hardwicki*).

#### Genus ANAMPSSES (Cuvier) Quoy and Gaimard, 1824

##### *Anampses pterophthalmus* Bleeker

*Anampses pterophthalmus* Bleeker, 1857, Acta. Soc. Sc. Indo-Néerl., 2, p. 81.

D.ix,12. P.12. A.iii,12. V.i,5. C.14.

Lat. line 52. Lat. trans. 9 : 19.

A specimen measuring 119 mm. total length was taken at Sharks Bay, May, 1954. A new record of this species for Australia.

Length of head 34 mm. (3.5), greatest depth of body 30 (4.0), greatest width of body 13 (9.1) in the total length 119 mm. Height of head 1.4 in its length. Eye 6 (1.8) in the snout and 1.5 in the convex interorbital space. Snout 11 (3.0) in the head.

Mouth small, slightly oblique. Maxillary not reaching to below anterior nostril. Lips thick. A single series of very small teeth in the jaws. Upper and lower jaw with two prominent incisors, directed forwards, compressed, with cutting edges. No posterior canines.

Body somewhat compressed, covered with small cycloid scales, those on back and thorax much smaller than those of sides. Head naked, except for the small pre-dorsal scales beginning behind the eye. Vertical fins without a basal scaly sheath. About fourteen pre-dorsal scales, very minute, most of which are embedded in the skin. Lateral line continuous, but sharply deflected below



posterior part of soft dorsal fin. About 34 to 35 scales in its upper part, 11 scales in the lower part. Lateral line canals short and unbranched.

Dorsal spines short and slender, the last spine 8.5 mm., 4.0 in the head. The longest ray 11 mm., equal to the length of the snout. Pectoral fins short, length 2.0 in the head. Ventrals very short, length 2.8 in the head. Third

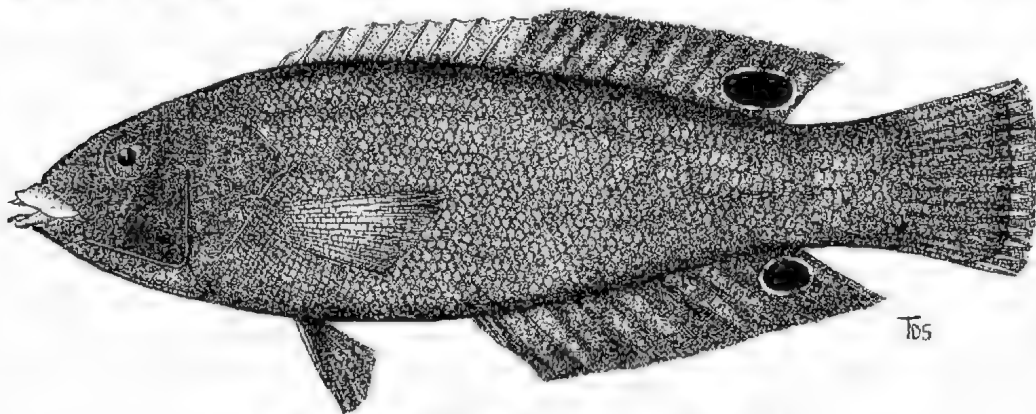


Fig. 5.—*Anampses pterophthalmus* Bleeker ( $\times \frac{1}{2}$ )

anal spine longest, length 8 mm., 4.2 in the head. Caudal rounded. Caudal peduncle compressed, rather deep, depth 7.5 in the total length.

*Colour in life*.—Body colour dark brown. Median fins all dark brown, caudal bordered by a narrow white band on the hind margin. A large black white-edged ocellus on the posterior dorsal and anal rays. Pectoral fins light yellow.

*Anampses lennardi* sp. nov.

D. ix, 13. P. 12. A. iii, 12. V. i, 5. C. 14.

Lat. line 29. Lat. trans. 4: 8.

Length of head 54 mm. (3.7), greatest depth of body 61 (3.3), greatest width of body 26 (7.4) in the total length 203 mm. Height of head 1.0 in its length. Eye 7.5 (2.5) in the snout and 1.9 in the strongly convex interorbital space. Snout 19 (2.8) in the head.

Mouth very small, rather oblique. Maxillary not reaching to below anterior nostril. Lips thick, upper lip much thicker than lower. A single series of minute teeth in the jaws. Both jaws with a pair of prominent anterior incisors, directed forwards, compressed and with cutting edges. No posterior canines.

Body oblong, compressed, covered with large cycloid scales, those before the dorsal and on the breast very small and embedded in the skin. Head naked, except for the small patch of pre-dorsal scales beginning behind the eye. Vertical fins without a basal scaly sheath. Lateral line continuous, sharply deflected below posterior part of soft dorsal fin. About 19 scales in upper part of lateral line, 8 in lower part. Each scale with a rather long unbranched canal.

Dorsal spines very slender and flexible, gradually increasing in length posteriorly, the last spine 19 mm., 2.8 in the head. Pectoral fins short and rounded, length 1.5 in the head. First ray of ventral fins somewhat produced, reaching past vent. Anal spines slender, the third longest, length 14 mm., 3.9 in the head. Caudal margin rounded, caudal peduncle short and deep, its depth 28 mm., 7.2 in the total length.

*Colour in life.*—Head, body and fins a bright yellow, with blue markings as figured. Three broad blue bars on the head, continued on to the middle of the body. Two of these bars cross the snout, and a further bar crosses the nape. Posterior part of body with blue bars and spots. Dorsal fin with a thin blue marginal band, below which is a series of round blue spots, on the membrane between the spines and rays. Membrane blue between bases of spines and rays. Pectoral fin plain yellow. Anal with thin blue bands as figured. Spine and first ray of ventral fin coloured blue, rest of fin yellow. Caudal fin yellow, with a thin blue band on the first and last ray.

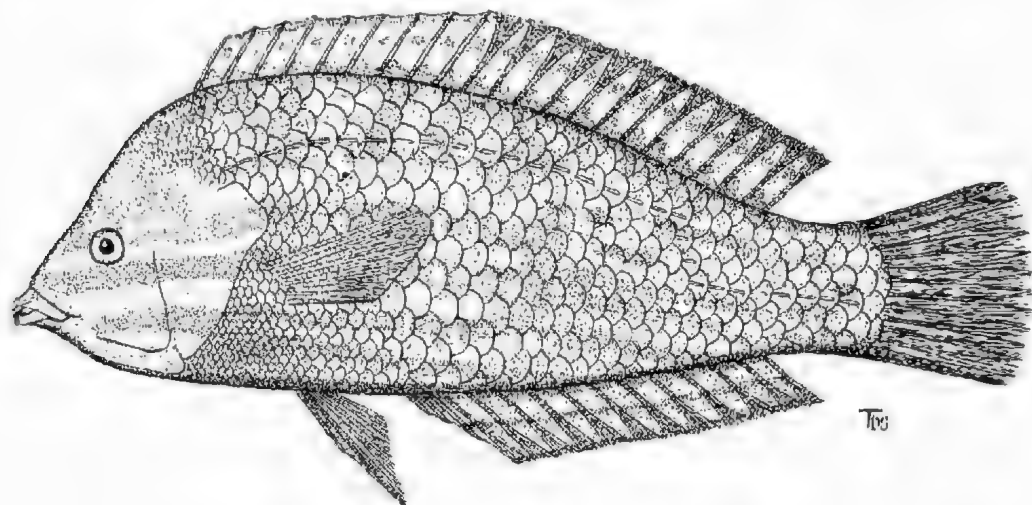


Fig. 6.—*Anaupses lemmardi* sp. nov. ( $\times \frac{3}{2}$ ).

Described from a male specimen 203 mm. total length taken at Point Samson, December, 1957. Type in South Australian Museum, Reg. No. F3021.

*Material examined.*—Two specimens measuring 203 mm. and 189 mm. total length.

*Affinities.*—Similar to *A. meleagrides* Cuv. and Val. in meristic features but differing in body proportions and colouration. The ventral fin is much more produced in *lemmardi*, the ventrals of *meleagrides* being shorter than the pectorals.

Genus *STETHOJULIS* Gunther, 1861

*Stethojulis rubromacula* sp. nov.

D.ix,11. P.13. A.iii,11. V.i,5. C.14.

Lat. line 28-29. Lat. trans. 2:7.

Length of head 32 mm. (3.8), greatest depth of body 34 (3.6), greatest width of body 17 (7.2) in the total length 122 mm. Height of head equal to its length. Eye 5 (2.6) in the snout and 1.6 in the convex interorbital space. Snout 13 (2.5) in the head.

Mouth very small, oblique. Maxillary not reaching to below anterior nostril. Teeth small, incisiform, in a single series in both jaws. No anterior canines, but a small posterior canine at corner of mouth. Lips rather thick. Premaxilla slightly protractile. Head naked, except for a few small scales embedded in the skin, beginning mid-way between the eye and upper angle of the operculum. Five to six pre dorsal scales.

Body covered with large cycloid scales, those of thorax larger than those of sides. Pre-dorsal scales smaller than those of sides. Vertical fins without a basal scaly sheath. Lateral line following the dorsal profile, sharply bent downwards before the caudal peduncle. Lateral line canals single, unbranched.

Dorsal spines short and slender, the first very short, smaller than the eye diameter. The last spine the longest, but not as long as the rays. Vertical fins short, not reaching vent. First anal spines minute, the third largest, equal to one eye diameter and a half. Pectoral equal to length of head without snout. Caudal fin rounded. Depth of caudal peduncle equal to snout.

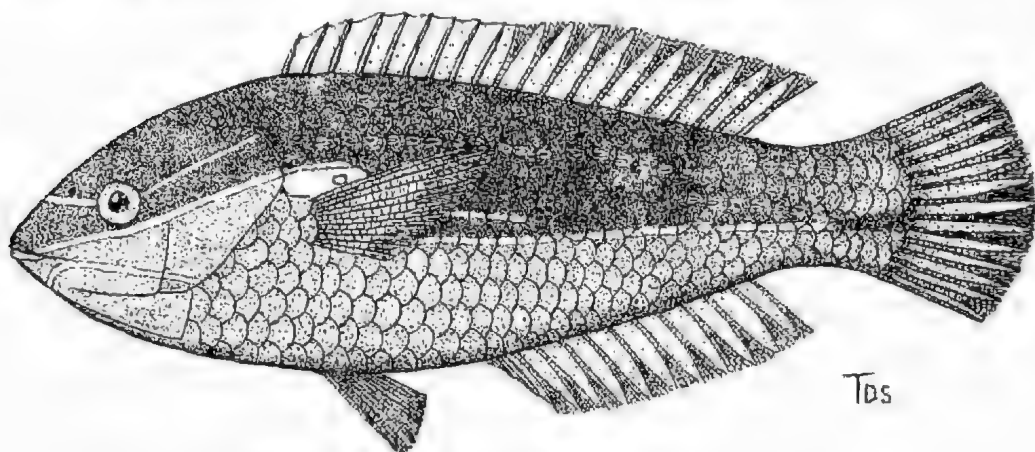


Fig. 7.—*Stethojally submacula* sp. nov. ( $\times 1$ ).

*Colour in life.*—Body colour olive green above, silvery white below. Three light blue lines on the face. The first passes horizontally from the dorso-frontal profile to the middle of the eye, thence upwards to the upper angle of the operculum. The second arises from the mouth and passes slightly obliquely upwards below the eye to the most posterior edge of the operculum, and continues on to the first 4 or 5 body scales above the pectoral fin. The third arises below the mouth, passes upwards on to the cheek, thence almost horizontally to the edge of the operculum. Upper part of head green, cheeks grading to yellow, chin pink. Body with two light blue lines. The first arises immediately behind the pectoral fin, and passes backwards horizontally on to about seven body scales. The second arises below the base of the pectoral, and runs back horizontally, ending about five scales before the beginning of the caudal rays. A dark band extends back from the end of this blue line across the caudal peduncle on to three rays of the caudal fin. The remainder of the caudal, and all other fins, are amber coloured. A large oval-shaped splash of red, immediately above the base of the pectoral fin.

Described from a specimen 122 mm. total length, taken Sharks Bay, May, 1954. Mr. Barrett-Lennard says that this appears to be about the maximum size to which this species grows.

Type in South Australian Museum, Reg. No. F2993.

*Affinities.*—Allied to *S. strigiventer* (Bennett) in meristic features but differing in body proportions, body colouration and number and distribution of bands on head and body. The silvery longitudinal bands of *strigiventer* are blue in this species, and the brown spot on the posterior dorsal rays and brown caudal cross-bars are lacking.

## Genus CHEILINUS Lacepede, 1802

*Cheilinus chlorourus* (Bloch)

*Sparus chlorourus* Bloch, 1791, Nat. Aust. Fische 5, p. 24, pl. 260.

A specimen measuring 232 mm, total length was taken at Point Samson, August, 1957. Add area 5 to Whitley's (1948, p. 26) distribution of this species in Western Australia.

## Family BODIANIDAE

## Genus CHOERODON Bleeker, 1849

*Choerodon rubidus* sp. nov.

D.xiii,7. P.17. A.iii,11. V.i,5. C.14. Br.6.

Lat. line 28-29. Lat. trans.  $3\frac{3}{4}$ : 9.

Length of head 57 mm. (3.7), greatest depth of body 63 (3.3), greatest width of body 28 (7.5) in the total length 210 mm. Height of head 1.1 in its length. Eye 12 (1.7) in the snout and 1.3 in the convex interorbital space. Snout 21 (2.7) in the head.

Mouth oblique, scarcely protractile, reaching to below posterior nostril. Upper lip thin, covered by preorbital when mouth is closed. Four peg-like canines in each jaw, the outer pair in the upper jaw much smaller than the inner pair. Canines of lower jaw small, the outer pair slightly flared out. Teeth behind the canines coalesced, forming a serrated ridge. No posterior canine.

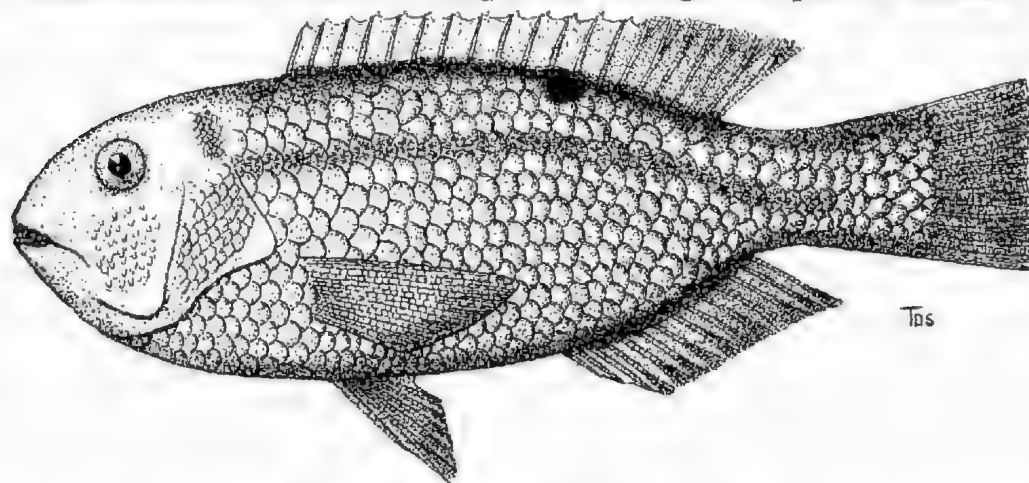


Fig. 7.—*Stethojulis rubromacula* sp. nov. ( $\times 1$ ).

Six to seven rows of small scales on the cheek. Operculum with five rows of much larger scales. Preoperculum finely denticulate. Scales on nape beginning above vertical through hind border of preoperculum. Body covered with large cycloid scales, which form a low basal sheath on the dorsal and anal fins. Lateral line complete, without a sharp deflection.

Six predorsal scales, twelve to thirteen preventral scales. Scales on thorax much smaller than on body. Dorsal spines short but pungent, the membrane behind them produced into a short filament. First spine equal to diameter of eye, the second spine the longest. Soft dorsal pointed behind, the last ray almost twice as long as the first.

Anal spines pungent, the third longest, but not as long as the first ray. Anal fin pointed behind. Pectoral fin rather long, the longest rays 4.4 in the total length. Ventrals pointed, reaching to the anus. Caudal truncate.

*Colour in alcohol.*—Body and fins coloured a uniform reddish brown, the fins without any conspicuous spots or markings. A small black spot on the back, immediately below the eleventh and twelfth dorsal spines, and covering the small scales forming the basal sheath of the dorsal fin.

Described from a specimen 210 mm. total length, taken Sharks Bay, May, 1954. Type in South Australian Museum, Reg. No. F2985.

*Affinities.*—Similar to *C. vitta* Ogilby in meristic features and body proportions, but differing in colour pattern, unevenly rounded shape of pectoral fin and truncate hind margin to the caudal fin. The caudal fin of *vitta* is emarginate, and the pectoral evenly rounded.

#### Genus *LEPIDAPLOIS* Gill, 1862

#### *Lepidaplois vulpinus* (Richardson)

*Lepidaplois vulpinus* Richardson, 1850, Proc. Zool. Soc. Lond., p. 71.

A large specimen measuring 435 mm. total length was taken at Hamlin Bay, January, 1955. Body and fins coloured a bright red. Membrane black between the first five dorsal spines.

Add area 3 to Whitley's (1948, p. 26) distribution of this species in Western Australia.

#### Family TRIGLIDAE

#### Genus *PARATRIGLA* Ogilby, 1911

#### *Paratrigla papilio* (Cuv. and Val.)

*Trigla papilio* Cuvier and Valenciennes, 1829, Hist. Nat. Poiss., 4, p. 80, pl. 73.

Two small specimens measuring 92 mm. and 95 mm. total length were taken at Perth, September, 1954.

Add area 3 to Whitley's (1948, p. 30) distribution of this species in Western Australia.

#### Family DACTYLOPTERIDAE

#### Genus *DACTYLOPTENA* Jordan and Richardson, 1908

#### *Dactyloptena orientalis* (Cuv. and Val.)

*Dactylopterus orientalis* Cuvier and Valenciennes, 1829, Hist. Nat. Poiss., 4, p. 134, pl. 76.

A small specimen measuring 172 mm. total length was taken at Point Samson, August, 1957. Add area 5 to Whitley's (1948, p. 30) distribution of this species in Western Australia.

#### Family OSTRACIONTIDAE

#### Genus *OSTRACION* Linnaeus, 1758

#### *Ostracion tuberculatus* Linnaeus

*Ostracion tuberculatus* Linnaeus, 1758, Syst. Nat., ed. 10, p. 331.

Two specimens measuring 345 mm. and 153 mm. total length were taken at Point Samson, December, 1957.

A new record of this species for Western Australia.

#### Family TETRAODONTIDAE

#### Genus *OMEGOPHORA* Whitley, 1934

#### *Omegophora armilla* (McCulloch and Waite)

*Tetraodon armilla* McCulloch and Waite, 1915, Trans. Roy. Soc. S. Austr., 39, p. 475, pl. 15.

A female specimen measuring 185 mm. total length was taken at Point Samson, December, 1957.

Add area 5 to Whitley's (1948, p. 32) distribution of this species in Western Australia.

An examination of 12 specimens of *Omegophora armilla* taken in Southern Australian waters during the past few years, shows that this species exhibits sexual dimorphism in its colour pattern. In the female the upper surface of the snout, back and tail are dark grey, this colour continued on to the sides behind the pectoral fins. There is a dark band passing from the eyes to below the snout. A black ring encircles the gill-opening and pectoral fin. The lower three or four rays of the caudal fin are dark brown to black.

The colouring of the male is similar, with the following additions. Blue spots on the head from the interorbital space to tip of snout. Blue longitudinal bars between front border of eye and tip of snout. Sides with blue spots extending down to level of ventral insertion of pectoral fin. A thin blue horseshoe-shaped bar encircling the pectoral fin, situated on the outer side of the black bar, and running parallel to it.

#### Family DIODONTIDAE

Genus *Diodon* Linnaeus, 1758

*Diodon holocanthus* Linnaeus

*Diodon holocanthus* Linnaeus, 1758, Syst. Nat., ed. 10, p. 335.

A specimen measuring 128 mm. total length was taken at Point Samson, December, 1957. This species is doubtfully recorded from North-Western Australia by Whitley (1948, p. 32) in area 5. It has been recorded previously from Queensland, New South Wales, Victoria, and erroneously recorded from South Australia by McCulloch (1929, p. 435).

#### Family ECHENEIDAE

Genus *Leptecheneis* Gill, 1864

*Leptecheneis neurates* (Linnaeus)

*Echeneis neurates* Linnaeus, 1758, Syst. Nat., ed. 10, p. 261.

D.xv,32. P.20. A.33. C.17.

A large specimen measuring 462 mm. total length was taken at Point Samson, August, 1955.

The edges of the soft dorsal and anal are bordered with a thin white band. Caudal with white margins, the central part black. A dark longitudinal band on the sides of the body.

Add area 5 to Whitley's (1948, p. 29) distribution of this species in Western Australia.

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# IDENTIFICATION OF VOLCANIC ASH IN SOILS NEAR MOUNT GAMBIER, SOUTH AUSTRALIA.

*BY J. T. HUTTON, G. BLACKBURN AND A. R. P. CLARKE*

## Summary

Soil samples that have been unmistakably affected by volcanic ash and collected from within 2 miles of the Blue Lake, Mt. Gambier, may contain up to 40 per cent. of particles in the range **2p-50p** diameter, and the particles in this range show a clearly defined straight line relationship between their amount and size. This feature is interpreted as representing accessions of volcanic ash. When a soil contains less than 4 per cent. of particles within this size group, it is considered that there is no significant amount of volcanic ash in the soil. Using these criteria, volcanic ash has been demonstrated in soils up to 10 miles from the Blue Lake and the approximate distribution of the ash is shown on a map. Almost all areas within 4 miles received volcanic ash but at greater distances the distribution was irregular. Ash soils were identified in the Mil Lei district 7 miles to the north-east and in the Caroline Forest 7 miles southeast of the Blue Lake.



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[Read 10 July 1958]

### SUMMARY

Soil samples that have been unmistakably affected by volcanic ash and collected from within 2 miles of the Blue Lake, Mt. Gambier, may contain up to 40 per cent. of particles in the range  $2\mu$ - $50\mu$  diameter, and the particles in this range show a clearly defined straight line relationship between their amount and size. This feature is interpreted as representing accessions of volcanic ash. When a soil contains less than 4 per cent. of particles within this size group, it is considered that there is no significant amount of volcanic ash in the soil.

Using these criteria, volcanic ash has been demonstrated in soils up to 10 miles from the Blue Lake and the approximate distribution of the ash is shown on a map. Almost all areas within 4 miles received volcanic ash but at greater distances the distribution was irregular. Ash soils were identified in the Mil Lel district 7 miles to the north-east and in the Caroline Forest 7 miles south-east of the Blue Lake.

### INTRODUCTION

The extent of volcanic ash around Mt. Gambier is of particular interest in South Australia, this being the best known of the few volcanic centres in the State. A detailed geological map of the Mt. Gambier area by Sprigg (1951) shows the boundary of this ash as no further than 3 miles from the Blue Lake, but observations made recently during a reconnaissance soil survey of County Grey suggested that the ash distribution extended to greater distances from this centre. In earlier accounts there had been a claim by Howchin (1909) of volcanic ash as far as 7 miles north-east of Mt. Gambier and a denial of this by Fenner (1921) whose map of the ash distribution is similar to that given by Sprigg (1951). The soils associated with the ash were described by Prescott and Piper (1929), who mentioned that the soil type is limited to within a 3 to 4 miles radius of the town, although in the north-easterly direction the limits are less clearly defined than in the south. Some of the samples listed by Prescott and Piper were taken, however, at distances greater than 4 miles from Mt. Gambier.

$^{14}\text{C}$  analysis of charcoal collected from the sand immediately below the bed of tuff at one site in North Terrace, Mt. Gambier, indicated an age of not more than 5,000 years (Fergusson and Rafter, 1957) and this is taken to be the maximum age of much of the volcanic ash ejected from the Mt. Gambier cone.

### FIELD OBSERVATIONS

The dunes of leached siliceous sands in the Mt. Gambier area are covered by several feet of tuff near the mountain and the contrast of the brown to dark brown soil and the compact tuff beds with the underlying loose white sand is clearly seen in new road cuttings, pits and auger holes. At 3 miles from the Blue Lake there is barely 2 feet of ash and at successively greater distances

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TABLE 1.  
Percentage of particles in range 2-10 $\mu$  and 10-50 $\mu$ .

Sample Number	Distance Mt. Gambier miles	Direction	Surface Soil			Sub surface			Underlying sand			Depth to buried soil in.
			Depth in.	2-10 $\mu$ %	10-50 $\mu$ %	Depth in.	2-10 $\mu$ %	10-50 $\mu$ %	Depth in.	2-10 $\mu$ %	10-50 $\mu$ %	
A464	1½	E	0.4	22	20	20-30	15	14				60+
A349	2	S	0.3	18	17	3.7	19	19				26
A350	2	S	0.3	21	21	3.6	20	20				24
18625	2	E	0.6	18	16	8-16	14	13				60+
A355	2	E	0.3	7	8	3.9	8	10				30
A363	2	NW	0.3	19	20	3.5	17	20	56-67	1	3	60+
A467	3½	NW	0.4	2	2	6.18	2	2				18
A364	3	S	0.3	13	17				36-53	1	0	30
A330	4	W	0.3	3	3	16-24	2	2	33-40	1	3	60+
A351	4	SE	0.2	10	11	2.6	11	11	27-34	1	2	27
A358	4	NE	0.3	2	2				42-57	0	1	10
A359	4	N	0.3	2	2	3-12	2	2	66-72	0	1	24
A360	4	N	0.3	8	8	6-10	11	9				27
A291	6	NE	0.3	5	5	6-12	5	4				10
A292	7	NE	0.4	6	8	10-15	5	5				18
A352	7	SE	0.3	3	4	16-24	2	2	22-40	1	2	19
												16+
A357	5	E	0.3	2	1	6-21	1	1				
5499	7	NW	0.6	1	3							
A361	7	N	0.3	1	2	12-27	1	3				
A340	8	S	0.3	1	4	7-12	1	2				
6315	9	SE	0.4	3	2	4-14	1	4				

the layer of compact tuff becomes thinner until it is no longer distinguishable from the surface soil of the dunes. These surface soils, however, are more like the soils of the ash zone than those on the dunes of leached siliceous sands 10 or more miles away. It is thought to be significant that the crests of dunes 5 to 7 miles from the Blue Lake have merited cultivation for cereals and after many crops the surface soils still retain sufficient aggregation to protect bare soil from erosion — circumstances which are not associated with sand dunes further from Mt. Gambier.

Mt. Schanek, the volcanic formation 7 miles south of Mt. Gambier, is probably similar to it in age and structure, but the area affected by its ash has not been studied in detail. The field observations of the soils near Mt. Schanek suggest that there is an overlap of the zones of ash distribution from the two centres and it is not possible, therefore, to clearly define the southern limit of ash from Mt. Gambier.

### SAMPLES

Soils and tuff layers were inspected at many points in the district and it was found that clearest evidence of volcanic ash could be obtained on the higher sand dunes, especially those identified by Sprigg (1951) as the Gambier and Caveton dunes. On the flat land between the dunes there is rarely such a contrast in texture and colour between ash and underlying soil and so most samples chosen for detailed study were from soil profiles associated with the dunes. Altogether, 46 samples from 21 profiles were studied and in addition to the surface samples, one or more samples from depths up to 6 feet were included. The profiles were all located between 1 and 11 miles from the Blue Lake, Mt. Gambier, and their location is shown in Fig. 1.

### METHOD OF LABORATORY EXAMINATION

The method used was essentially that described by Hutton (1955) for the particle size analysis of soils. The plummet balance was used to measure the amount of material of particle size less than  $5\mu$ ,  $10\mu$  and  $50\mu$  as well as that less than  $2\mu$  and  $20\mu$ , the usual limits for clay and silt plus clay. Material larger than  $20\mu$  was separated by an automatic decantation unit (Hutton, 1955) and then divided into 5 fractions using appropriate sieves. Ten points were thus obtained from which the particle size summation curves, such as those shown in Fig. 2, could be drawn.

### RESULTS

The outstanding feature of the summation curves is the lineal portion between  $2\mu$  and  $50\mu$ . Four typical curves are shown in Fig. 2. For convenience of comparison these curves show the distribution of the material greater than  $2\mu$  and the straight line is considered to indicate the unsorted fine volcanic ash. On a logarithmic plot, the mid point between 2 and 50 is 10 and hence a straight line on the summation curve between  $2\mu$  and  $50\mu$  is indicated by the percentage in the range  $2\mu$  to  $10\mu$  being equal to that in the range  $10\mu$  to  $50\mu$ . Table 1 sets out some of the results obtained and it has been divided into two parts to indicate the presence or absence of volcanic ash.

### DISCUSSION

The results in Table 1 show that close to Mt. Gambier up to 40 per cent. of the particles in the surface are in the range  $2\mu$  to  $50\mu$  but further out the percentage of particles in this range falls off rapidly. When the percentage is less than 4, it is considered that the accession of volcanic ash has not been significant.



By defining volcanic ash as material with more than 4 per cent. of unsorted particles in the range  $2\mu$  to  $50\mu$ , it has been possible to delineate the area around Mt. Gambier that came under the influence of the showers of ash ejected during its volcanic activity. The boundary is naturally ill-defined but within the limits imposed by the number of samples examined it is considered that the area indicated in Fig. 1 received accessions of volcanic ash.

Close to the actual source, particularly if there is more than 20 per cent. of material in the range  $2\mu$  to  $50\mu$ , the relatively high amounts of acid soluble phosphorus and potassium confirm the presence of material of igneous origin (Prescott and Piper, 1929, and unpublished data, C.S.I.R.O., Division of Soils). When, however, the amount of ash is low, phosphorus and potassium may not be reliable indicators, as both elements are translocated by plant growth and tend to accumulate in the surface of soils.

The map showing the ash distribution supports the earlier claim by Howchin (1909) of ash 7 miles north-east of Mt. Gambier. The irregular shape of the ash zone north of Mt. Gambier may help to explain the difficulty mentioned by Prescott and Piper (1929) of defining the north-easterly limits of the ash shower as compared with the southerly limits.

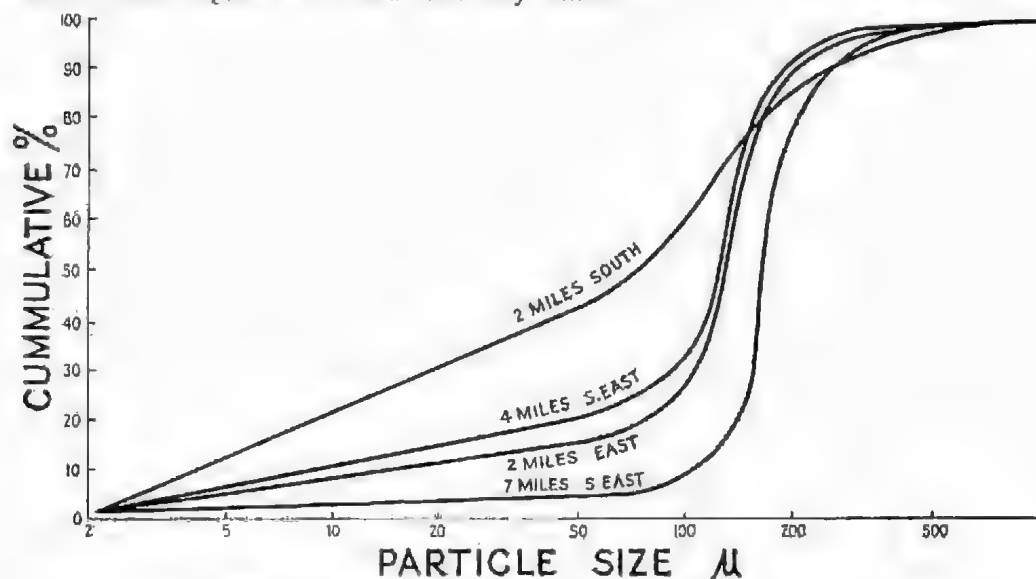


Fig. 2.—Representative particle size summation curves.

The distribution of ash indicated by Fenner (1921) was regarded by him as being governed by winds similar in direction and velocity to those of the present day, while Gill (1950) suggested that for south-west Victoria the prevailing winds approximately 5,000 years ago were from the north-west. The map presented in this paper suggests that the distribution depended mainly on south-west, north-west and north winds, but it is quite possible that the irregular distribution resulted from different wind effects prevailing during a limited number of eruptions.

#### ACKNOWLEDGMENTS

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# **NOTES ON THE GEOMORPHIC HISTORY OF THE AREASURROUNDING LAKES ALEXANDRINA AND ALBERT, SOUTH AUSTRALIA.**

*BY C. J. DE MOOY*

## **Summary**

The geomorphology of an area surrounding Lakes Alexandrina and Albert is discussed. Two stranded coastal dune ranges were mapped in detail and tentatively correlated with the former coastlines in the south-eastern Province by methods of photo-analysis. Three consecutive stages of construction were recognized in the younger range. The origin and mode of deposition of the black clay plains surrounding the lakes are discussed. Evidence of two former mouths of the River Murray is presented. Crocker's hypothesis of formation of the present aeolian topography during a Recent Arid Period (Flandrian transgression) is rejected. It is postulated that the redistribution of sands by aeolian activity occurred in Pleistocene arid cycles and was interrupted by periods of stability of the landscape. It is suggested that stages of construction of beach ridges, periods of consolidation and soil formation alternated with periods of aeolian redistribution during each glacial and interglacial cycle.



# NOTES ON THE GEOMORPHIC HISTORY OF THE AREA SURROUNDING LAKES ALEXANDRINA AND ALBERT, SOUTH AUSTRALIA.

by C. J. DE MOOY\*

(Communicated by R. C. Sprigg)

[Read 10 July 1958]

## SUMMARY.

The geomorphology of an area surrounding Lakes Alexandrina and Albert is discussed. Two stranded coastal dune ranges were mapped in detail and tentatively correlated with the former coastlines in the south-eastern Province by methods of photo-analysis. Three consecutive stages of construction were recognized in the younger range.

The origin and mode of deposition of the black clay plains surrounding the lakes are discussed. Evidence of two former mouths of the River Murray is presented.

Crocker's hypothesis of formation of the present aeolian topography during a Recent Arid Period (Flandrian transgression) is rejected. It is postulated that the redistribution of sands by aeolian activity occurred in Pleistocene arid cycles and was interrupted by periods of stability of the landscape. It is suggested that stages of construction of beach ridges, periods of consolidation and soil formation alternated with periods of aeolian redistribution during each glacial and interglacial cycle.

## I. INTRODUCTION

Some information on the Quaternary geomorphic history of the area surrounding Lakes Alexandrina and Albert emerged from an analysis of the landscape made during a reconnaissance soil survey (de Mooy, in press).

It is a complex area. The present and former coastal dune ranges abut on the eastern slopes of the Mount Lofty Ranges. The stranded shorelines enter the area from the south-east and reach their lowest elevation here due to progressive downwarping in the same direction (Sprigg, 1952). Large tidal lakes occupy the central depression between the stranded coastal dunes and the Mount Lofty Ranges. The River Murray and several smaller rivers discharge into the lakes and flow through the Murray Mouth into the ocean. Waterlaid deposits around the present lakes therefore have a lacustrine as well as a tidal and estuarine character. Changing sea levels in combination with negative tectonic movement, and changing climatic conditions have influenced this landscape.

The geomorphology and stratigraphic relationships of the surface layers are the main sources of information. These are supported by limited micro-palaeontological data. A soil survey, even on a reconnaissance basis, supplies unusual detail about stratigraphical relationships of surface layers. In the area under review it was found that the distribution of certain groups of soils mapped at the level of the soil combination correlates well with the extent of the geomorphic elements of the landscape.

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## II. GEOLOGY

The thickness of the Pleistocene cover of the region varies greatly. Howchin (1929), dealing largely with country further east, gives an average thickness of 20 feet. The materials are largely sands, clays and lime. Limestone is abundant; it is the aeolianite described by Crocker (1946a) with the exception of the non-fossiliferous limestone in the northern portion of the area (Seymour combination, figure 1), which is referred to as "travertine limestone" by Crocker.

Underlying is level-bedded fossiliferous Tertiary limestone, which also has a variable thickness (Howchin, loc. cit.). The Miocene Murravian Gulf covered the entire area and extended far over the New South Wales and Victorian border. The Gambier limestone and its equivalents, deposited during this transgression, have been recorded in the area. Howchin (1929) recorded 60 ft. thick Miocene marine beds from a bore at Cooke Plains starting at 139 ft. below sea level. King (1950) mentioned outcrops of Miocene bryozoal limestone in the area comprised by the Hundreds of Malcolm, Coolinong and Seymour. The Oligocene "Janjukian" stage of the Gambier limestone was identified from samples taken during the soil survey from section 305, Hdl. of Seymour, by Dr. N. H. Iardbrook (personal communication), who also discovered Pliocene deposits along the Murray cliffs between Tailem Bend and Wellington. Tate (1900) identified Eocene beds in the Hundred of Brinkley.

The Tertiary marine beds rest upon Precambrian crystalline bedrock, usually granites of varying composition, which outcrop in several places (e.g. near Tailem Bend and Lake Albert). Permian tillites and boulder clay have been reported by King (1950) to occur above the bedrock and in depressions.

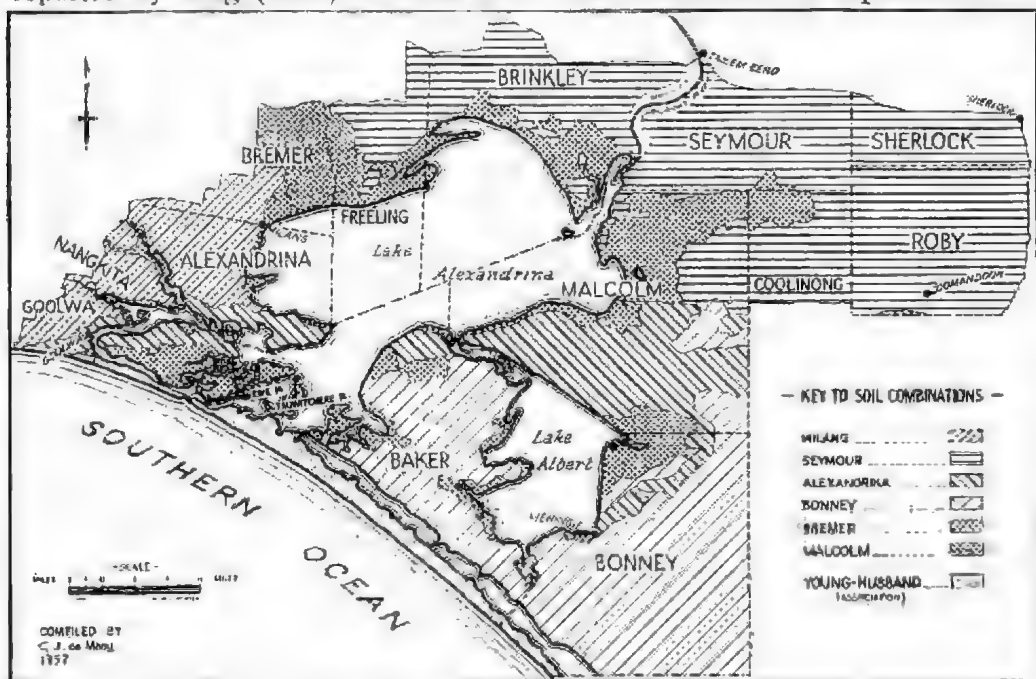


Fig. 1.—Soil combination map.

## III. GEOMORPHIOLOGY AND SURFACE STRATIGRAPHY

### (a) *The Soil Combinations*

The area is composed of 7 distinct geomorphic units which are equivalent to soil combinations.

1. *The Milang combination* consists largely of alluvial and colluvial deposits of a clayey nature. It is situated on the eastern slopes and in the plains at the foot of the Mount Lofty Ranges, which grade gently towards Lake Alexandrina. During upheaval and dissection of the Mount Lofty Ranges the Currency Creek and Finnis River carried materials from the hills, including lateritic gravel, which were deposited in the older terrace and plains along the rivers (EC and RB in Figs. 2 and 3). This and two lower aggradational terraces bear witness of former high sea levels (plate 1, fig. a). The middle terrace is mapped as the Currency Creek-a association (CC-a). Its soils have textural differentiation. The low terrace (CC-b) could correspond as to elevation with

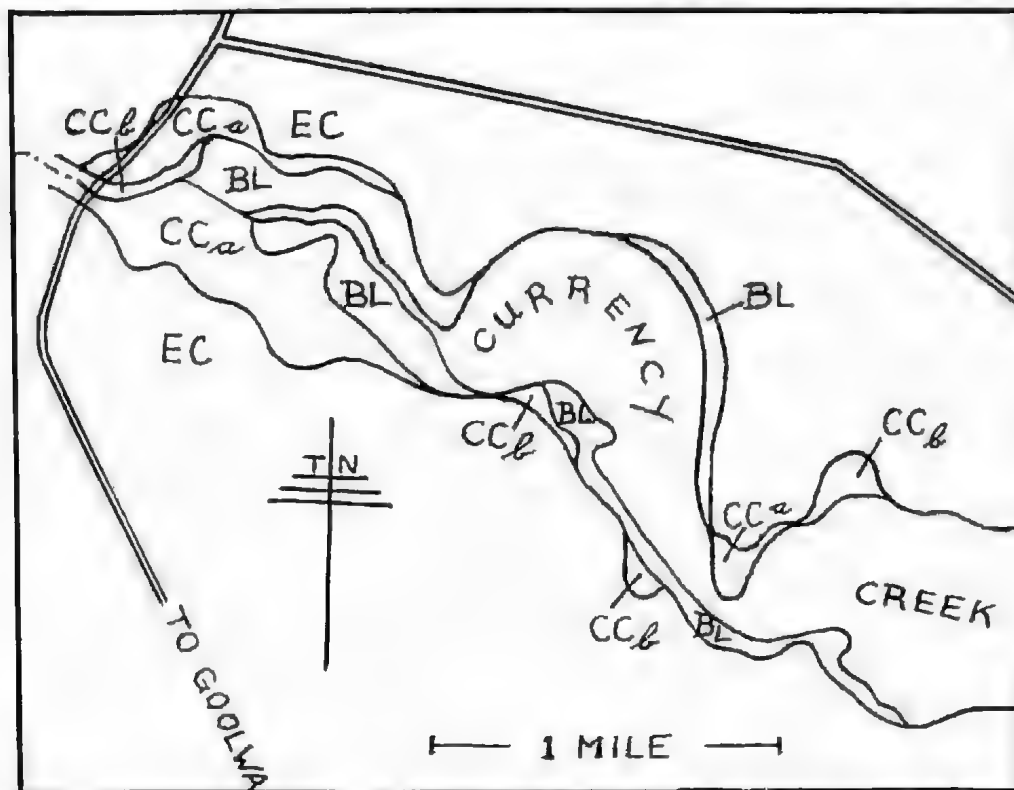


Fig. 2.—Fragment of soil association map showing river terraces along Currency Creek. Legend figures 2 and 3: EC—East Currency association; RB—River Bank association; CCa—Currency Creek a association; CCb—Currency Creek b association; BL—Black Swamp; W—open water.

the Malcolm deposits (see Fig. 1). It is remarkable that soil formation in both deposits has been restricted to structural development and redistribution of carbonates.

2. *The Seymour combination* may be regarded as portion of the Mallee country extending eastward across the Victorian border. It consists of gently undulating plains of Pleistocene age. It grades gently seaward and was traced to some feet below sea level underlying the Malcolm combination. The materials are predominantly coarse textured, redistributed by aeolian activity, and commonly travertinized near the surface. West of the River Murray the plains extend north beyond the surveyed area to the foot of a range, which it is suspected represents a former coastal dune range. Its approximate position be-

tween the 100 and 150 foot contour lines is sketched in Fig. 6. Its shape has been influenced during formation by the River Murray. This suggests that deltaic conditions prevailed in the plains south of Murray Bridge and in much of the Seymour combination during this period of higher sea level. Repeated redistribution of sands formed several N-S transverse dune ridges in the Seymour unit as well as a superimposed WNW-ESE ridge topography.

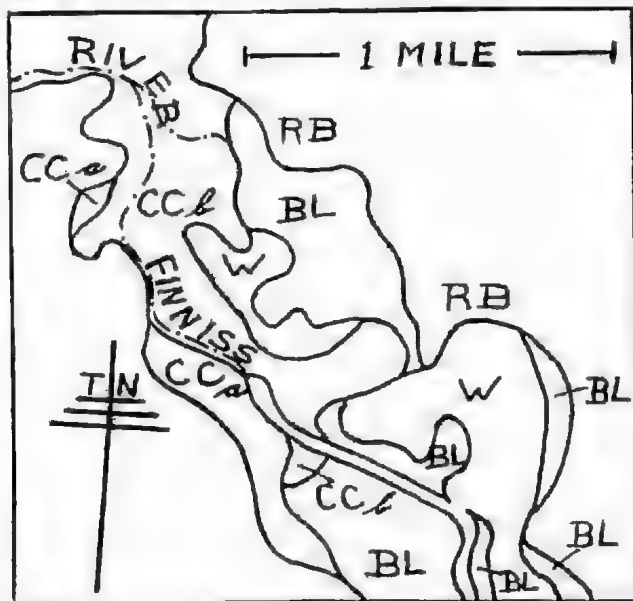


Fig. 3.—Fragment of soil association map showing river terraces along the River Finniss.

3. *The Alexandrina combination* is a steep former coastal dune range with an aeolianite core. In places it is ridged to a WNW to ESE direction. No geomorphological significance can be attached to the spur curving around the Malcolm combination to the south. For reasons of soil mapping convenience this spur of deep leached sands was included.

4. *The Bonney combination* is another stranded coastal dune system with irregular or SW to NE trended undulating to hilly topography. It has a core of aeolianite.

5. *The Bremer combination* was formed by alluvial activity of the Bremer and Angas Rivers. The alluvium can be divided into an older and a younger phase. The older deposits, the Bremer Plains and Lakes Plains associations have eroded the ridged Seymour and Milang combinations. The material was subsequently redistributed by aeolian activity to its present gently undulating topography, which can be distinguished from the older surrounding country by the absence of E-W sand ridges. Subsequently, soils of the Red-Brown Earth type developed on the fine sandy micaceous sediments. Finally, up to 10 feet of younger alluvial materials (Angas Plains and Langhorne Creek associations) locally buried the soils formed on the older material. The latest deposition of this material overlies the Malcolm clays, which in turn overlie the soils of the older alluvium. The distribution of the old and young alluvial deposits in relation to the pre-existing ridged landscape is illustrated in detail in Fig. 4.

6. *The Malcolm combination* is largely composed of fine textured lacustrine and estuarine sediments at low elevation.

7. The Youghusband association is the present coastal dune range consisting of unconsolidated calcareous sands. The area can be subdivided into a relatively stable dune landscape, and a system of SW-NE drifting sands, which

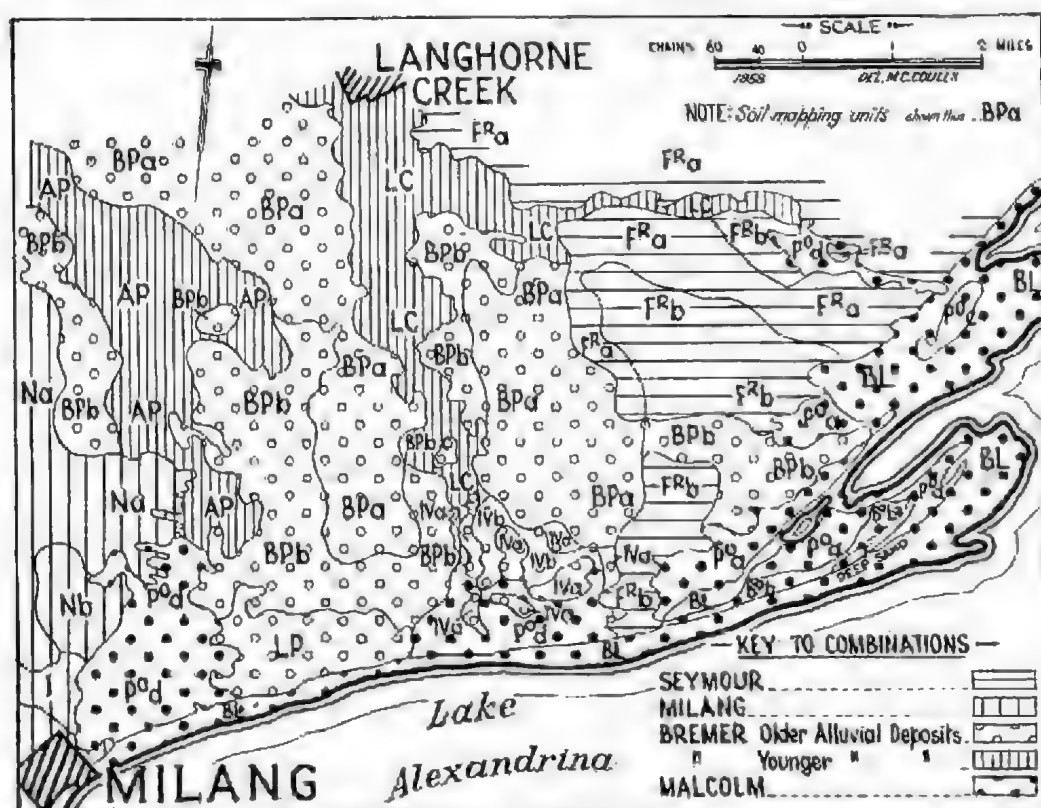


Fig. 4.—Fragment of soil association map showing the distribution of the alluvial deposits in relation to the older ridged landscape.

are moving in from the coast and gradually covering the former. The stable dune landscape is steep, has a thick vegetative cover and decalcified swales.

Further subdivision of these units and greater detail is given in the soil association map (de Mooy, in press).

#### (b) Stranded Coastal Dunes in the Area

The stranded coastal dunes in the area have an aeolianite core. The term aeolianite, variously named calcareous aeolianite, coastal limestone, sandy limestone or calcarenite, has been used by Crocker (1946a) for both consolidated and unconsolidated windpiled calcareous material which consists largely of sands, fragmental shells and foraminifera. Fairbridge *et al.* (1952) gave the following general description: "Coastal limestone is a medium grained clastic sediment in which the grains consist mainly of fragmental calcareous algae, mollusca, foraminifera and bryozoa with varying amounts of inorganic constituents and a cement of secondary calcium carbonate." Aeolianite in the lakes area is comparatively siliceous, which may be related to the proximity of the Murray Mouth. It contains only small fragments of shells. This applies in a larger degree to the Alexandrina than to the Bonney system.

### 1. The Alexandrina Coastline

The Alexandrina coastal dune range has a strong relief. It rises sharply from Lake Albert to elevations of 100 and 150 ft. Here the range is up to four miles wide. WNW-ESE sand ridges, pronounced in several places, have largely been re-distributed presumably under a south-westerly wind component. The regular soils are sandy, deep or shallow, and, without texture differentiation, occupy swale positions in certain areas. The soils are separated from the underlying aeolinite by travertinized limestone which contains no shell fragments. Commonly there are two sheets of this nature, separated by soil materials.

The Alexandrina coastline runs in approximately E-W direction. It can be followed across the lakes to Goolwa and abuts against the foothills near Middleton.

### 2. The Bonney Coastline

The Bonney coastal dune range runs parallel with the present coastline and follows the inner edge of the Coorong. The accompanying dune range of

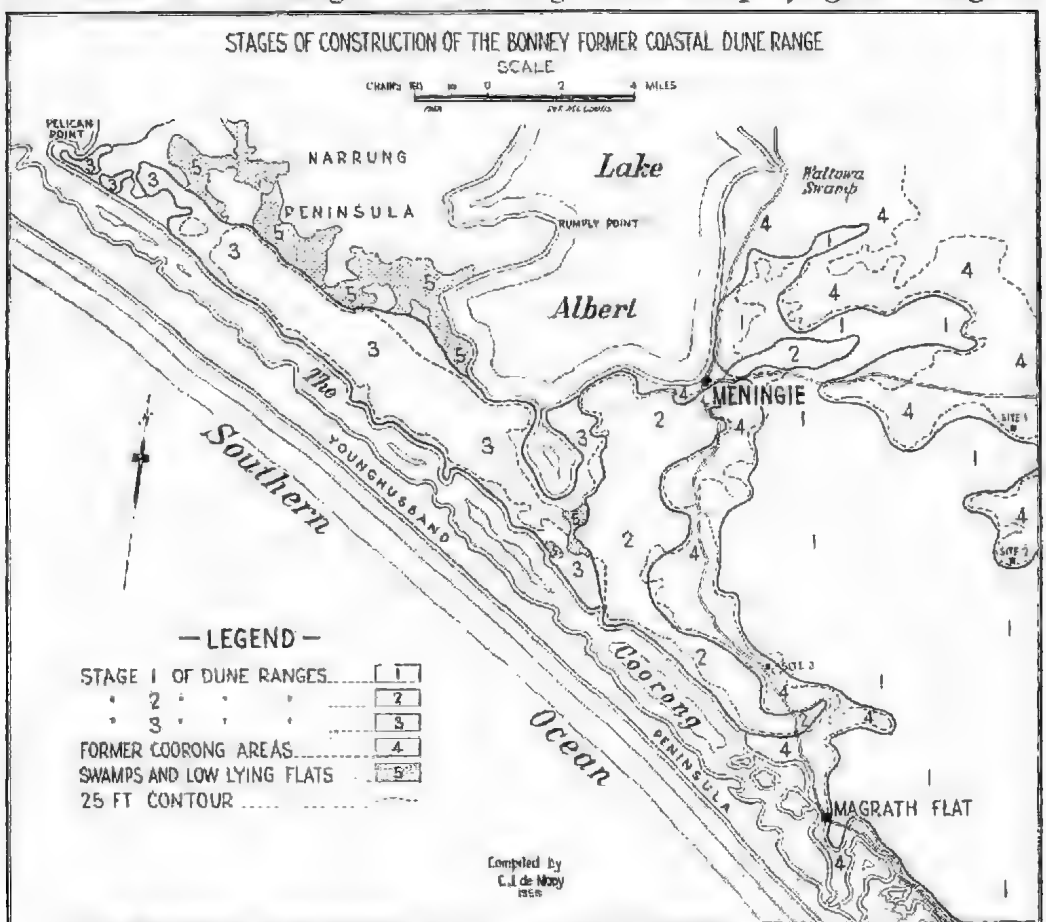


Fig 5.—Stages of construction of the former Bonney coastal dune range.

approximately 1 to 2 miles width is relatively steeper than inland areas and reaches elevations of 50 to 100 feet. This Bonney Range terminates at Pelican Point on Narrung Peninsula. The soils can be easily distinguished from those of the Alexandrina Range. The decalcified sandy soils directly overlies the traver-



tinized crust of aeolianite, which contains coarser and more shell fragments than the Alexandrina Range. The leached sands have been re-sorted by wind action. This has not led to drastic separation from limestone areas and the landscape has preserved much of its original topography.

Cluser examination of the morphology reveals that this unit was constructed in three stages. The older stage is outlined by the 25 ft. contour, which follows the Bonney coastline for many miles along the Coorong in a north-westerly direction. At Magrath Flat it turns inland along the Princes Highway. East of Meningie the coastal dunes smooth out to a large plain at an elevation of approximately 25 ft. above sea level. This flat could represent a former Coorong associated with the first stage of the dune range. This is confirmed by micro-palaeontological information obtained from semi-consolidated calcareous sands at 3 to 4 ft. below the surface in section 214, Hd. of Bonney (site 1 in Fig. 5). The assemblage contains the foraminifera *Lagena*, *Cassidulina*, *Rotalia* and *Globigerina*. Nearby the micro-fauna consisted of *Triloculina tricarinata* d'Orbigny, *Miliolinella oblonga* Montagu, *Elphidium simplex* Cushman, *Discorbis dimidiatus* Jones and Parker. *Chara* and *Ostracoda*. The foraminifera indicate deposition under protected conditions in shallow water with limited access to the sea. *Succinea* shells occur sporadically in the assemblage. They could have entered this Coorong with the wind from the seaward dune ranges. The fauna at site 2 (section 206, Hd. of Bonney) consists of *Coxiella*, *Elphidium simplex* Cushman, five species of *Ostracoda*, *Chara*, and a small land gastropod and indicates deposition in protected brackish water, into which gastropods are readily washed.

During the second stage of construction the Bonney coastline was extended to the place where Lake Albert comes nearest to the Coorong. It is separated from the previous stage by a strip of low-lying land where Coorong-like conditions prevailed during formation of the dune. It has a somewhat lower elevation than the former Coorong East of Meningie and chains of pipeclay swamps occupy the lowest positions. Cross-bedding in the aeolianite was found to represent lagoonal deposition (site 3) similar to that taking place now along the seaward side of the Coorong.

The final stage of construction took the Bonney coastline to Pelican Point. There are chains of swamps just inland of the dune range (unit 5 in Fig. 5) and former channels which the River Murray maintained for some time between the dunes of the second and third stage. If these swamps represent a Coorong, it has a lower elevation than those of the first and second stages.

The subdivision of the Bonney dune range in three parts correlates well with the distribution of various soils in the Bonney combination; the East-Meningie, Meningie and Baker associations respectively (see soil map, de Mooy, in press).

The East-Meningie soils are characterized by a grey surface sand, a bleached subsurface merging into yellow sand and sometimes a thin, weakly developed texture — B horizon.

Typical Meningie soils lack the bleached layer and the B horizon. The Baker soil is an undifferentiated brown sand over aeolianite. On the basis of the geomorphic history outlined above, it may be suggested that these soil differences are primarily related to the factor time. If these striking differences are indeed related to time of soil formation another older phase could possibly be distinguished in the East-Meningie association. This phase includes the sands near the Alexandrina system. Here boulders of laterite have formed on the slopes of limestone ridges exposed to south-westerly winds, whereas com-



monly in the East-Meningie association only light ironstaining is found on limestone. Also, the texture B horizon is better developed in this area.

The various stages as brought out by the 25 ft. contour from military maps and modified by geomorphic and general soils evidence are sketched in Fig. 5.

### 3. *The Relationships Between the Former Coastal Dunes in the Area and those in the South-East*

The stranded shorelines in the south-eastern province have been studied extensively by Tindale (1933 and 1947), Hossfeld (1950) and Sprigg (1952). Sprigg mapped them in detail up to County MacDonnell and discussed their downwarping to the north-west under the influence of the rising Mount Lofty Ranges. He calculated the degree of tilt of various dunes, starting from the idea that the flats immediately in front of the dune approximately represent the original foreshore and that they were level when the dunes were formed. He found a progressive decrease in downwarping from the older to the younger dunes and therefore that the warping has been fairly continuous throughout the formation of this sequence. Using his figures and assuming that the rate of downwarping of the dunes to the north is constant, the tilt of these dunes can be extrapolated over the remaining distance to Lake Albert. The toe of the Naracoorte Range would therefore be at an elevation of 50 ft. above sea level (L.W.O.S.T., Port Adelaide) and at 13 ft. below at Narrung. The Peacock, East Avenue and West Avenue Ranges would be at respectively 50, 7 and 13 ft. below sea level when reaching Lake Albert. The Reedy Creek Range would enter the Hundred of Bonney at 7 ft. elevation and fall to 2 ft. below sea level near the Murray Mouth. The Waukwine Range would be at 40 ft. below sea level in the Hd. of Bonney. It must be suspected that the toe of the dunes in the lakes area which is commonly at a few feet above lake level, are adapted to more recent deposition and not representative of the ancient shoreline, which may be submerged. One of the places where it is believed that the original Alexandrina shoreline can be observed, is south of Goolwa (plate 1, fig. b). This far end of the shoreline was probably near enough to the rising Mount Lofty Ranges to be little influenced by downwarping.

To relate the formations of the lakes area to the system of stranded coastal dunes in the South-East more conclusive results than from elevations may be expected from a study of the topographic continuity of the south-eastern shorelines to the north. The aerial photographs of the area between County MacDonnell and the lakes district were analysed by stereoscopic interpretation.

Sprigg's geological map (1952) and a soil map of an area surrounding Tintinara (Jackson and Litchfield, 1954) provided basic information to extrapolate from. The results are reproduced in Fig. 6. The geographical distribution and nomenclature of the ranges as defined by Sprigg (1952) were adopted. The West Avenue and Peacock Ranges and an unnamed range following the landward shore of the Coorong could be traced over a long distance northward into County Cardwell. The unnamed range along the Coorong consists of two parts with different topography. They have been distinguished as units 3 and 4 in Fig. 6. Unit 3 is typified by a topography of beach ridges parallel with the coastline. Towards the western fringe their height decreases. Unit 4 is an undulating dune range without a special trend. It is evidently older than unit 3. It is inconspicuous in County MacDonnell and was not mapped by Sprigg. Further north in County Cardwell the proportions of the irregular dune landscape of unit 4 increase. Simultaneously swamps gain significance in the ridged unit 3 and this terminates at Salt Creek. Unit 4 continues and ultimately becomes part of the Bonney dune landscape, which is a much larger formation. A

possible explanation for the asymmetry of unit 4 is a greater accumulation of sands in the proximity of the former Lake Albert channel of the River Murray. Another explanation is that other ranges as well contributed to the Bonney landscape.

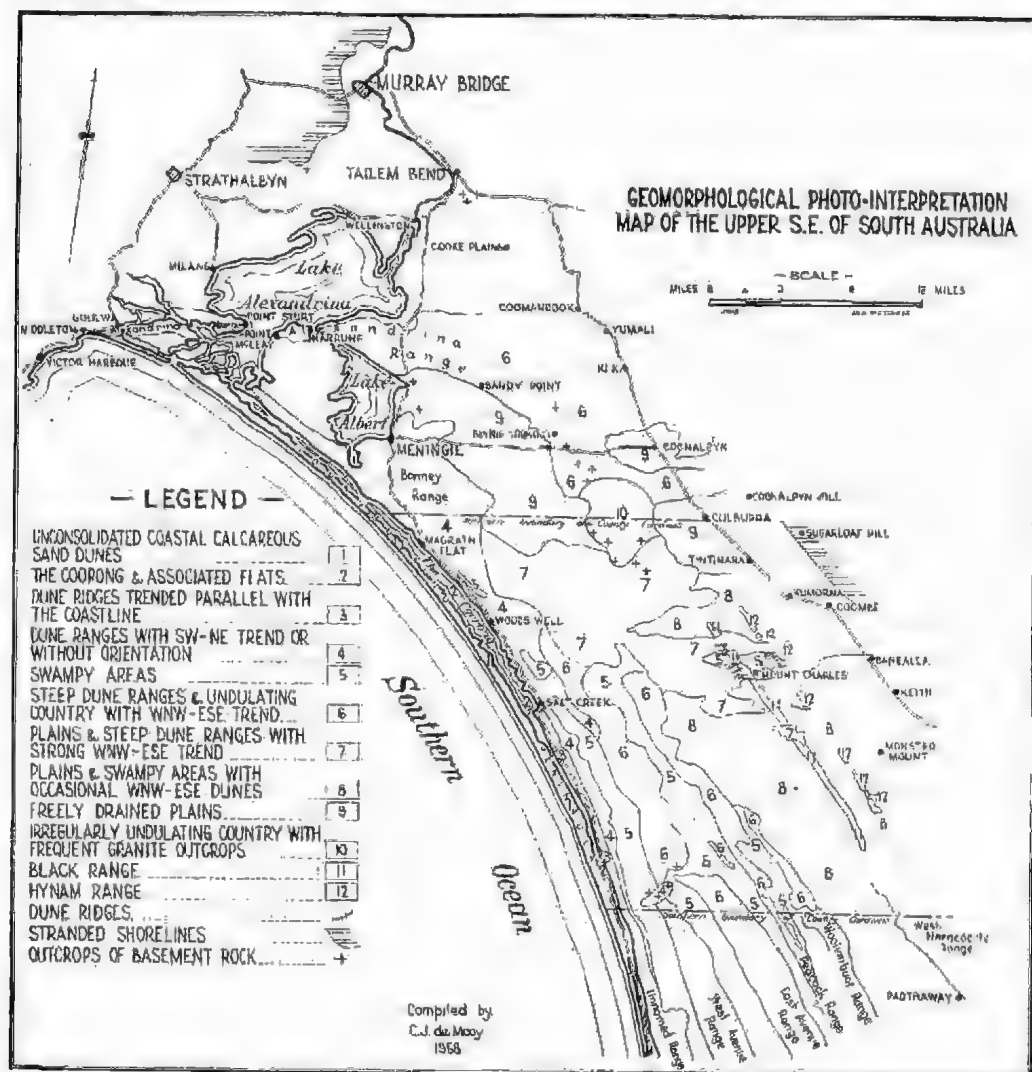


Fig. 6.—Geomorphological photo-interpretation map of the Upper South-East.

Earlier correlations have been made by others. Tindale (1947) claims to have traced the Woakwine Range over a distance of 230 miles from the Glenelg River to Lake Alexandrina. He includes the East and West Dairy Ranges in the Woakwine Terrace and mentions a break at Kingston. At Lake Albert Tindale suggests that a later phase runs along the Coorong shore towards Hindmarsh Island and that an earlier phase forms the northern shore of Lake Albert and runs down to Narrung and Point McLeay. Tindale attempted to trace the Reedy Creek Range northwards to the River Murray. His Reedy Creek Range correlates with Hossfeld's (1950). It joins the West Avenue Range north of the

Hundred of Murrabinna, County MacDonnell. This is shown as the West Avenue Range on the present map in accordance with Sprigg's nomenclature. Tindale presumes that it can be correlated with a sandy ridge between Wellington and Tailem Bend, primarily on considerations of height above sea level. He does not account for differences in height with the South-East due to tectonic movements. It follows further from the soil association map (de Mooy, in press) that these deep sand ridges (Mason Hill association) and their topography do not continue over long distances.

Hossfeld (1950) and Sprigg (1952) in more recent work have shown that the Woakwine Range bends out to the ocean and terminates at Cape Jaffa. Sprigg claims that it is the Reedy Creek Range that can be followed from Victoria to the mouth of the River Murray. The course of the Reedy Creek Range north of Reedy Creek (East of Kingston) is not clear from Sprigg's map. He mapped many parallel beach ridges, following the Coorong at the landside and related them to more recent "Woakwine truncation" and "Anadara high" sea levels. This is unit 3 in Fig. 6. Since then remnants of an older dune range have been discovered amongst these younger ridges, and Sprigg (personal communication) now regards them as possible remnants of the Reedy Creek Range. Some of them are shown on the Kingston geological sheet.

From a combination of this evidence with Fig. 6, it appears to be the Reedy Creek Range (unit 4) that contributed to the formation of the Bonney landscape.

Just north of the area mapped by Sprigg the distinct and straight shorelines disappear, due probably to the effect of progressive downwarping in this direction. The West Avenue Range and others to the east of it as well as the interdunal swamps have been affected by strong redistribution of sands in an E-W direction.

The original limits of the various geomorphic units have been obscured by this aeolian activity. Swampy areas traversed by occasional E-W steep dunes give the impression that the movement of sands occurred when the ground water level was lower than at the present time. The boundaries must be regarded as a simplified outline of the elements of the landscape. Apart from redistribution in E-W direction at a later stage, the ranges have also been influenced during their formation by granitic outcrops. Granite is, for example, responsible for the small inclusion of unit 4 in the West Avenue Range (see Fig. 6).

The Naracoorte Range is discontinued at the northern limit of County MacDonnell. Hossfeld (1950) considers that it divides here and that one branch continues to the NW. This is known as the Black Range (unit 11). It is a distinct formation which, however, shrinks to inappreciable size towards its northern extremity. An entire *Cardite* shell (identification B. C. Cotton) recovered from the aeolianite at the northern limit of the range by Mr. G. Blackburn and the author confirms its formation as a coastline. The Black Range and the remains of the Hynam Range to the east of it (unit 12), although older than the ridges to the west, have themselves not been affected by the widespread redistribution of sands in E-W direction. They terminate SW of Tintinara. Continuing in the same direction a range of considerable volume can be distinguished northward from the hilly Mt. Boothby landscape characterized by granitic outcrops (unit 10). This range has a volume comparable to the Alexandria Range and meets the Alexandria combination at the eastern limit of the soil-surveyed area. The deep sands of the oncoming range are of the Bonney type (East-Meningie association, de Mooy, in press) and it is clear that they join a pre-existing landscape here. They partly overlie the local Alexandria soils which continue for some distance due east along the 100 foot contour

line. Portions of the Alexandrina combination and particularly the portion mapped as the Ashville association during the soil survey, possibly served as a core for the forming coastal dune landscape as was the case with the Mount Boothby unit. Perhaps it is significant in this respect that Sprigg (personal communication) claims that the coastal dune range running east of Keith and Tintinara in a north-westerly direction bends westward towards Binnies Look-out. A fraction of this range was mapped by Jackson and Litchfield (1954) and is reproduced in Fig. 6. It probably joins up with the Naracoorte Range via Mount Monster and is the same range as referred to by Hossfeld (1950) as the West-Naracoorte Range.

A possible connection between the south-eastern ranges and the Mount Boothby granite area has been obscured by a system of steep E-W sand hills (unit 7). The regular alternation of ranges and interdunal swamps can no longer be recognized here. It appears that the E-W alignment noticeable over the entire area of County Cardwell has joined the ranges. The reason may be that the ranges converged here as suggested by Hossfeld (1950), possibly combined with the influence of pre-existing granite outcrops. The entire sheet of E-W dunes could have been formed in the one operation, but for one observation: no E-W orientation is obvious in a fringe along the Coorong. Here the dominating trend is SW to NE (unit 4, Fig. 6). Going east across the boundary between units 4 and 7 there is a merging increase of E-W orientation, while at first the original trend is still recognizable. This rather suggests that several periods of E-W trending are involved, alternating with SW-NE trending in every newly formed dune range. The effect of each following E-W redistribution of sands here overlapped and amplified the effect of the former, while the last Pleistocene coastal dune unit failed to experience E-W redistribution of sands. This possibly will be dealt with further in the discussion of the acolian activity in the area.

From the mode of contact of the E-W dunes with the Black and Hyam Ranges it appears that they crossed those ranges, while the latter showed no signs of instability or movement of their materials.

Evidently no complete topographic connection of former coastlines can be made. If further remains occur in the E-W trended dune landscape, detailed soils inspection could provide the information required to reconstruct a further extension of the ranges.

The available information suggests that the Alexandrina Range of the lakes area corresponds with the Black Range, although this has a considerably smaller volume, and further with the Naracoorte Range. The coastline was in places deformed by pre-existing formations, sometimes having a granitic core.

#### (c) *The Malcolm Deposits*

During the last period of greater extent of the lakes Alexandrina and Albert there was extensive sedimentation in low-lying surroundings of the present lakes. Its maximum extent is marked by the outline of the Malcolm combination (Fig. 1). Black, fine-textured materials containing up to 70 per cent. clay particles form the principal deposit. It is certain from the contact of the Malcolm combination with the surrounding country that this sedimentation activity post-dates all other deposition and acolian activity in the area with the exception of recent alluvial deposition along the Angas and Bremer Rivers ("younger alluvial deposits" in Fig. 4) and sand drift caused by human beings.

The Malcolm deposits were laid behind the shelter of the present coastal dune range as an extension of the alluvial clays along the lower course of the River Murray. The mode of deposition, although of estuarine character, varied considerably in various portions of the area. East of the lakes Alexandrina and

Albert there were shallow embayments where near-lacustrine conditions prevailed. Towards the island near the Murray Mouth brackish water sedimentation occurred under greater tidal influence. In the Hindmarsh association many sharply defined, curving depositional creeks fingered out into the plains (Pl. 1, Fig. C). The deposition was a very slow process, continuing for a long period.

The original landscape was not disturbed. The thickness of the deposits is related to the topography of the landscape prior to flooding. Depressions received more than rises which may have only one foot of clay. A buried soil overlying limestone can usually be detected within 6 feet from the surface. Movement of water to and fro followed the low-lying central areas and an occasional well-defined connecting channel. Blind Creek which has previously been mistaken for a former stream bed of the River Murray (Tindale, 1947) is one of them.

The maximum level of the deposits can be estimated from the extent and maximum level of the floodwaters of the River Murray in 1956. The 1956 floods are the highest on record. They were unable to inundate a considerable portion of the Malcolm clays in higher positions. Records in the Engineering and Water Supply Department state maximum flood levels of 111.3 ft. R.L. at the Goolwa barrages, 113.05 ft. R.L. at Milang, 113.02 ft. R.L. at Meningie and 115.85 ft. R.L. at Wellington. Taking the mean sea level at the Murray Mouth as 103.75

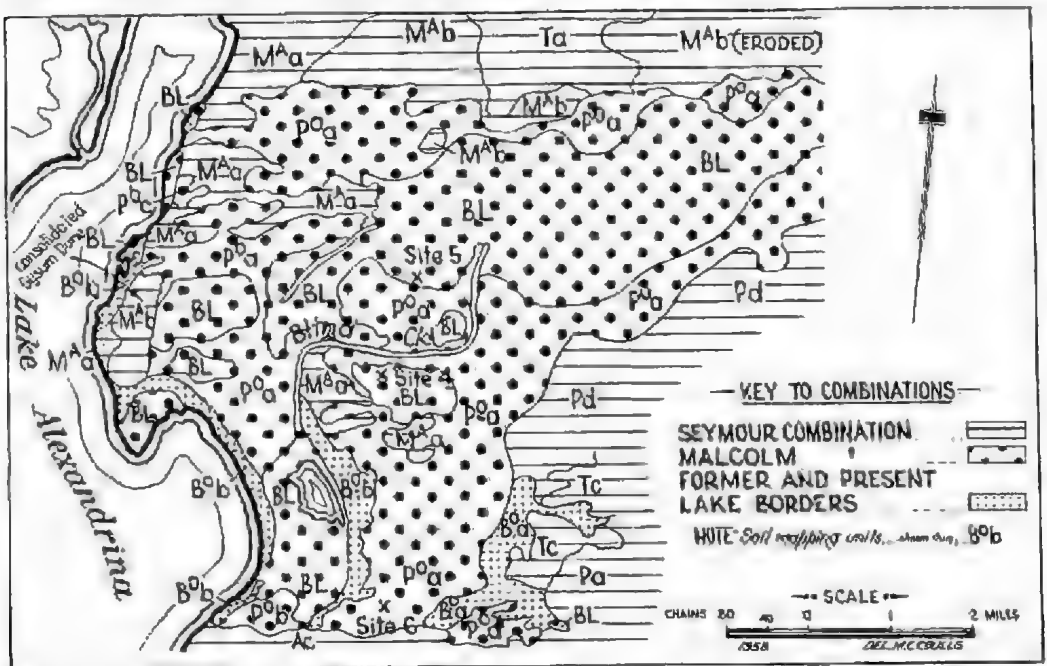


Fig. 7.—Fragment of soil association map showing three parallel borders of Lake Alexandrina.

ft. R.L., it appears that a water level 10 ft. above the sea is insufficient to cover the entire Malcolm deposits. In addition to that, if subsidence is considered to have been negligible, there is still shrinkage of the sediment to account for. The clay was probably subjected to similar shrinkage as that in the bed of Lake Albert for which Taylor *et al.* (1931) found a loss of volume of 80 to 90 per cent. on air drying. It means that the depositing waters reached at least



several feet above the present rises. River floods would have had to be banked up by a higher sea level to reach this level. Traces of a 10 ft. higher sea level are abundant along the Australian coast and it is possible that the Malcolm deposits reached their greatest extent and height during that period.

Retreat of the high lake level occurred by degrees. During its maximum extent Lake Alexandrina formed a border through rearrangement of local materials. This border, B°-a in Fig. 7, runs three miles east of the lake, parallel with the present edge, and joins ridged land that preserved its original topography (P d). On this ridge developed a soil profile with distinct texture change. A second former lake border developed approximately one mile from the lake. It represents a standstill of the retreating water level, or a return after a more complete retreat. The coarse, sandy soil has no textural development, it overlies the original heavy clay where this was not first removed by wave action. The third sandy border formed at the present lake edge. This evidence can be correlated with phenomena in those swales of the present coastal dunes, deep enough to be affected by groundwater. The level of the groundwater in the narrow dune range would fluctuate with the level of the sea. It appears that pauses in the lowering groundwater formed concentric rings in the sand which are now marked by different vegetation through different salinity conditions (Pl. 2).

The origin of the material and the conditions of deposition are borne out by micropalaeontological examination of samples taken from the area east of Lake Alexandrina, Tauwichee Island and Ewe Island. The foraminifera assemblage revealed considerable differentiation in the conditions of sedimentation both geographically and between various sedimentary horizons of the one profile. East of Lake Alexandrina no foraminifera could be found in the clay deposits at sites 4, 5 and 6 in Fig. 7 to conflict with freshwater deposition, nor in the buried soil at site 4. It is interesting that only a thin layer at 63 to 66 inches below the surface, at the top of the buried soil, bears witness of an incursion of brackish water by virtue of an assemblage including: *Elphidium simplex* Cushman and *Ostracodes*.

On Tauwichee Island (see Fig. 1) the microfauna including *Trochammina inflata* Montagu is indicative of brackish water deposition. Closer to the Murray Mouth on Ewe Island the assemblage while reflecting more saline sedimentary conditions also indicates that the materials were deposited while protected from direct contact with the ocean. The microfauna consists of sponge spicules and the foraminifera. *Trochammina inflata* Montagu, *Discorbis* sp., *Globigerina bulloides* d'Orbigny, *Planorbulina mediterraneensis* d'Orbigny, *Elphidium macellum* Fichtel and Moll, and other *Elphidium* sp., and "*Rotalia beccarii*" Linne. Some of the planktonic foraminifera on Ewe Island may have been washed through the nearby Murray Mouth. Evidently the present coastal dunes were in existence prior to deposition of the Malcolm clays. This is in accordance with the retreat of sea level by degrees, as is recorded by the swales of the coastal dune range.

Subsequently the diatoms at site 4 were examined to render further information on the depositional environment of the presumed fresh water horizons devoid of a foraminiferal assemblage. The diatoms *Campylodiscus clypeus* and *C. echenies* are common and there are a few specimens of *Hyalodiscus laevis*. This is a brackish water assemblage. It remains the same with depth, but the diatom content increases greatly at 57 to 60 inches, approaching the top of the buried soil, for which the foraminifera indicated a brackish environment. If diatoms may be used to draw ecological conclusions for this area where the

environment varied considerably with the distance from the Murray Mouth, it would appear that freshwater conditions never prevailed.

(d) *Periodicity of Formation of gypsum and pipeclay*

*Deposits and Their Relative Age*

The material known as pipeclay in the Coorong flats is, in fact, a dolomitic lake-marl deposit according to Mawson (1929), whereas Jack (1921) suggests that the pipeclay at Meningie and along the Coorong is flour gypsum. Rather similar material taken from swamps during the soil survey of the lakes area proved by chemical analyses to be a mixture of gypsum and dolomite. Pipeclay swamps are found in depressions east of the lakes in places where Malcolm clay deposits had no access. They overlie undisturbed buried soils.

Jack (1921) extensively dealt with the varieties, distribution and origin of the gypsum deposits of South Australia. He discussed three possible sources for gypsum deposits:

1. Decomposition of sulphides to sulphates in the presence of limestone.
2. Derived from sea water when an arm of the sea is cut off by a bar, permitting sea water intake to keep pace with evaporation.
3. Concentration from cyclic salts in evaporating areas, while excess sodium and the more soluble salts would be carried to the sea by the gradual circulation of groundwater.

He considers the "pipeclay" swamps near Meningie and Cooke Plains to be part of the former extension of Lakes Albert and Alexandrina. They were then more readily accessible to sea water and would act as efficient evaporating pans. At Cooke Plains gypsum dunes piled up subsequently.

This view is also taken by King (1951), who states that the gypsum deposits are related geologically to the old lake bed, where they crystallized. He relates the formation of gypsum on the bed of the saline flats and the commencement of accumulation in dunes to the gradual emergence of the land after the inundations during the high sea-level period of the middle Recent. King found impure granular gypsum overlying concretionary limestone in shallow testholes in the "pipeclay flats". The limestone carried an assemblage of marine fossils "typical of the middle Recent period" including *Coxiella*, *Diala lauta* and abundant foraminifera.

The soil survey, however, has shown that the history of development is somewhat more complicated. The "former lake bed" can be divided into two formations:

1. A low-lying portion of the Seymour combination where the "pipeclay" and the gypsum dunes were formed (Fig. 8).
2. The black clay deposits of the Malcolm combination which extend from Lake Alexandrina to just east of Cooke Plains. They are a younger formation and overlie the Seymour combination. It has been pointed out that these materials, which probably originated during the latest greater extension of the lakes contain no foraminifera. This suggests that the formation of the gypsum deposits at Cooke Plains may predate the formation of the lake bed indicated by the Malcolm combination. They may be related to the top of the buried soil at 5 ft. depth below the surface, which witnessed an incursion of relatively brackish water according to its microfauna.

Conditions for the accumulation of gypsum dunes apparently prevailed periodically. Howchin (1929) recorded several beds of gypsum alternating with



sandy limestone in a bore at Cooke Plains. Actually, the Malcolm combination abuts on smaller gypsum dunes at the windward side of the pipeclay flats (see Fig. 8), which may represent an earlier phase of gypsum dune formation. Older gypsum dunes occur due west of Cooke Plains along the channel of the Murray River (Fig. 7). Here they have subsequently been eroded and have undergone several cycles of aeolian activity. Sands have been deposited over them, soil profiles formed and stripped to limestone making them identical with the soils

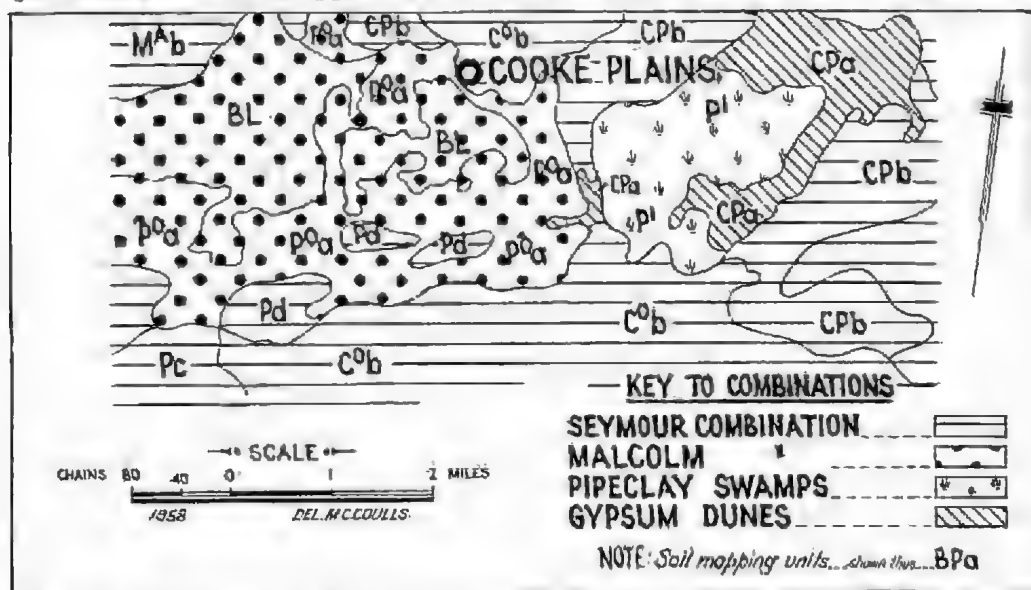


Fig. 8.—Fragment of soil association map joining Fig. 7 to the west and showing the geographic relationships between the Malcolm deposits, pipeclay swamps and gypsum dunes.

of the Seymour combination. The gypsum is present in crystalline form, whereas the dunes at Cooke Plains are unconsolidated and composed of seed gypsum. One explanation for the false bedding described by Tate (1882) is that a Pleistocene high sea level inundated these older dunes.

#### (e) Former Mouths of the River Murray

Howchin (1929) has stated that the Coorong may represent a former outlet of the Murray when the river had a more southerly position, from which it has been gradually driven northward by the encroaching sand ridge.

Taylor and Poole (1931) suggested that the River Murray at some stage flowed through Lake Albert to join the Coorong. They recognized silted up river channels and mentioned a cut-off billabong in Meningie Bay. The soil survey provided further evidence that the Murray at one stage maintained some channels across the Bonney Range. A system of depressions (unit 5 in Fig. 5) nearly joins the toe of Lake Albert with the Coorong. Presumably the river channel through the present Lake Albert became confined to this passage upon construction of the third stage of the Bonney dune landscape, when also the inlet of the ocean was transformed into the lake; contrary to Howchin's view the present coastline was not in existence at that time. Finally, the main channel shifted to Lake Alexandrina.

Another former outlet of the River Murray was found south of Goolwa (Pl. 3, Figs. a and b). Seaward of, and at lower elevation than the Alexandrina shoreline, which is well preserved here, the small creek draining the Middleton

association, and the estuarine Hindmarsh deposits converge to the site of a former opening in the present dunes. The dunes are locally narrow and relatively low.

(f) *Periodicity of Aeolian Activity and the Theory of Pleistocene Climatic Changes*

The strongly WNW-ESE orientated dune ridges of the Seymour combination are superimposed on a gently undulating landscape also originating from aeolian activity, without such orientation. West of the River Murray it is clear that after soils had formed the old landscape was stripped down to a lime-enriched horizon by renewed aeolian activity and remnants of the redistributed sands formed the present dunes. Formation of this landscape required two periods of instability and aeolian activity (Pl. 4, Fig. a).

East of the River Murray three transverse dunes running approximately north to south can be recognized. They have a considerably larger volume than the E-W dune ridges. In a section from Wellington to Sherlock (Fig. 9) the first dune (Mason Hill association) is followed by an E-W ridged landscape (Perkindoo association). This peters out in stony plains (Tailm Bend associa-

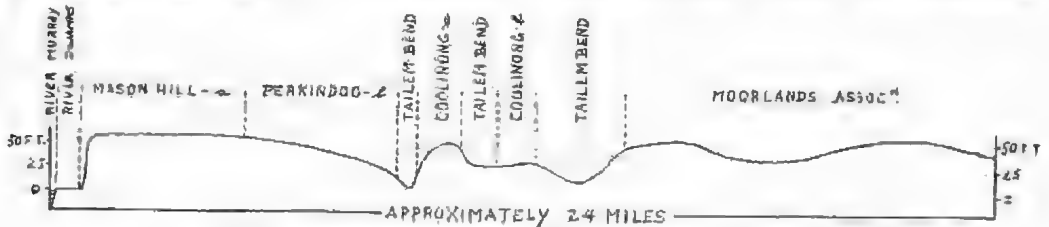


Fig. 9.—East-West section between Wellington and Sherlock.

tion). The second transverse dune (Coolinong-a) rises sharply from the plains and is followed by parallel longitudinal dunes (Coolinong-b) which merge into stony plains. The third dune is the westernmost part of the Moorlands association.

The first system is differentiated into deep sands (Mason Hill) on the dunes, a ridged landscape with finer textured subsoils and plains with stoney soils. This becomes lost in the eastern units. In the second system the soils of the ridged landscape intrude upon the range itself and in the third dune the limestone follows similarly. This suggests that the third dune has undergone more stages of erosion and soil formation than the other two. An older age for the third dune is also indicated by the fact that it is overlain by the soil pattern of the second dune in places. The formation of transverse dunes may be explained by repeated activity of the same winds which formed the longitudinal dune ridges. Transverse dunes could form where there is an abundant supply of sands, whereas self dunes could form when materials become scarcer. A connection between the origin of the transverse dunes and the shores of former extensions of Lake Alexandrina is unlikely, because the dunes are parallel to the gradient of the country.

The Alexandrina combination has also been influenced by several periods of wind activity as indicated by two sheets of travertinized limestone, overlying aeolianite (Pl. 4, Fig. b), and finally there is the repeated formation of gypsum dunes, mentioned earlier.

Redistribution of sands in the Bonney landscape has not greatly disturbed the original topography. A SW to NE trend is evident in areas of steep topography. If there has been redistribution of sands in an E-W direction the effect

has been weak. It may be concluded that the formation of the Bonney landscape post-dates all or at least most of the aeolian activity which resulted in WNW-ESE dune alignment elsewhere. The situation in the Seymour and Bonney combinations is in agreement with the impression gained by stereoscopic examination that an E-W orientation is superimposed on the originally NE trending former coastal dunes in County Cardwell (units 6 and 7, Fig. 6) and that the westernmost dune range (unit 4) has preserved its predominantly NE trend.

There is general agreement that the south-eastern coastal dune ranges date from the Pleistocene. This certainly applies to the Bonney Range, which from correlation with its south-eastern equivalents may be related to the Great interglacial (according to Sprigg, 1952), or the Penultimate Glaciation (according to Hossfeld, 1950). Hence the formation of WNW-ESE sand ridges of the older units in the area which actually extend over a large portion of southern Australia also dates from the Pleistocene period. This is in contrast with the hypothesis postulated by Crocker, who relates the distribution of leached sands to a severe Recent Arid Period of some 3,000 to 6,000 years ago (Crocker, 1946a and b). Further supporting evidence is that the alluvial deposits of the Bremer combination eroded the older Seymour and Milang combinations, which at that time already had their E-W orientation fully developed.

Several soils formed on the Bremer materials have been sampled and their mechanical analysis compared with those from the Milang combination in Table I. Firstly, it is clear that the soil materials of profiles A227, 229, 232 and 235, representing the Milang landscape, have a typical mechanical composition. They contain practically no silt and have a rather constant coarse to fine sand ratio. These (Solodized Solonetz) soils have a very sharp texture contrast between the surface (A) and subsoil (B) horizon. The ratio is remarkably constant vertically also and both horizons are genetically strongly related. Secondly, the soils of alluvial origin of the Milang (A230, 231 and 239) and Bremer combinations have a much lower coarse to fine sand ratio quite distinct from those of the old landscape. They contain an appreciable amount of silt. In this respect the young alluvial soils (A400, 405 and 425) are best provided. These figures indicate that no mixture of materials between the two units occurred, not even in the small alluvial inclusions within the Milang combination, which is to be expected if there were two separated periods of aeolian activity.

It would be untenable to maintain that the sand ridges of the Milang combination originate from the Recent Arid Period, because in that case deposition of the Bremer materials coupled with removal of portion of the ridged landscape, followed by aeolian redistribution into gently undulating plains without specific trend, subsequent formation of mature soils and deposition of the Malcolm deposits as well as younger alluvium should all post-date the Recent Arid Cycle. The geomorphology of the lakes area is rather in agreement with the hypothesis furthered by Fairbridge *et al.* (1952) who concluded that evidence in Western Australia corresponds closely with the conclusion reached in Morocco that successive generations of aeolianites correspond to interglacial periods. Each major cycle of dunes and high shorelines was separated from the next by erosional phenomena of a short period when sea level was considerably lowered. The maxima of the pluvials correspond to the glacial maxima when all the climatic belts migrated equatorwards and temperate-wet climates interrupted the desert conditions when the aeolianites were formed.

Fairbridge (1953) and also Hossfeld (1950) associated the suggestion that erosive cycles occurred repeatedly during the Pleistocene period with the theory



of climatic changes as expressed by Flint (1945), Keble (1947) and Gentili (1949).

Flint claims that glacial periods of the regions affected by glaciers were replaced by pluvial periods at lower latitudes, during which the climate was relatively moist and cool while the interpluvial periods were characterized by warmer and drier climates. His hypothesis, based on fluctuations of atmospheric turbulence, allows for a number of erosive cycles during the Pleistocene.

Keble (*loc. cit.*) and Gentili (*loc. cit.*) expressed the opinion that during glacial maxima most of Australia was covered by humid, cool forest. This would be due to the advanced temperate belt during the expansion of the glaciers. During glacial minima the north would be under superhumid forest, while the south would still fall in a subhumid woodland zone. This would be associated with the expansion of the wet equatorial belt. It follows from this that during each major glacial and interglacial cycle the arid climate belt would move across the Australian continent twice, theoretically creating two cycles of unstable vegetation and landscape in general.

Regarding the alignment of longitudinal dunes in relation to the prevailing winds, Barkley (1935) pointed out that the direction of the Mallee sand dunes appears to be determined not by the prevailing winds which are north in winter and south in summer (*s.i.c.*) but by the direction of the strongest gusts accompanying the change of wind.

The prevailing winds of the present day, however, create a north-easterly trend in the coastal dunes and it is difficult to see how the WNW-ESE dune ridges could be in balance with them. Yet they are longitudinal dunes which developed parallel to the direction of the dominating wind at the time of their formation.

Madigan (1936, 1938, 1946) showed that the sand dunes of the Australian deserts are everywhere longitudinal ridges. Their trend is parallel to the direction of the prevailing wind, which varies in different parts of the desert. The general trend in the Simpson desert is to the NNW.

The hypothesis of migrating climatic belts offers an explanation for the direction of the Mallee dune ridges, whereby the wind regime associated with each climate is not affected. Southward shifts of the climatic belts during periods of decreasing glaciation can even account for recurrence of those desert conditions, separated by periods of dominating south-westerlies.

Such a theory even if it is an over-simplification of the real climatic fluctuations is quite able to explain the formation of the landscape in agreement with field observations: formation of the visible coastal dune ranges as unconsolidated sands during Pleistocene high sea levels, aeolian redistribution in SW to NE direction under subsequent arid conditions, leaching of lime and soil formation in temperate-wet climates of the glacial maxima, E-W redistribution of leached sands under unstable landscape conditions during subsequent aridity and permanent coastal dune formation when the sea level approaches a new maximum level.

#### IV. ACKNOWLEDGMENTS

Grateful acknowledgment is made of the work by Dr. N. H. Ludbrook of the Department of Mines, South Australia, who carried out the palaeontological determination of the environmental conditions of deposition from soil samples submitted.

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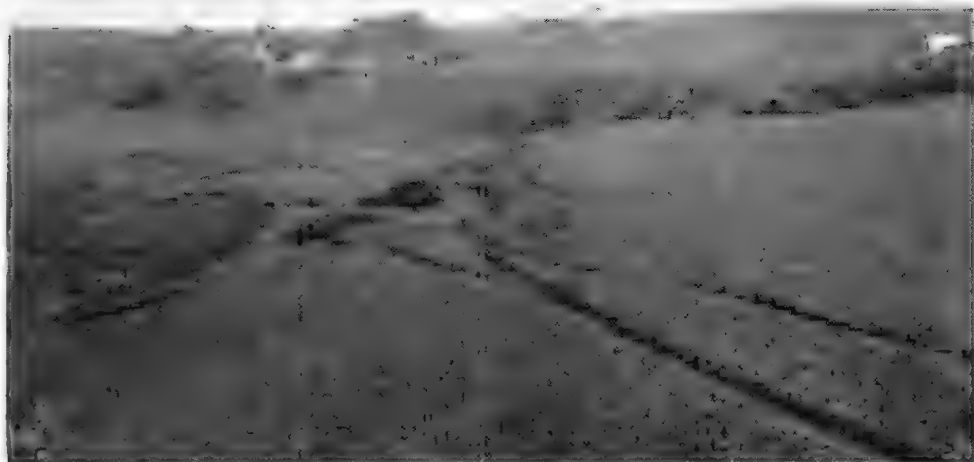


Fig. a.—View of river terraces at Currency Creek. Middle terrace (CCa) in foreground.

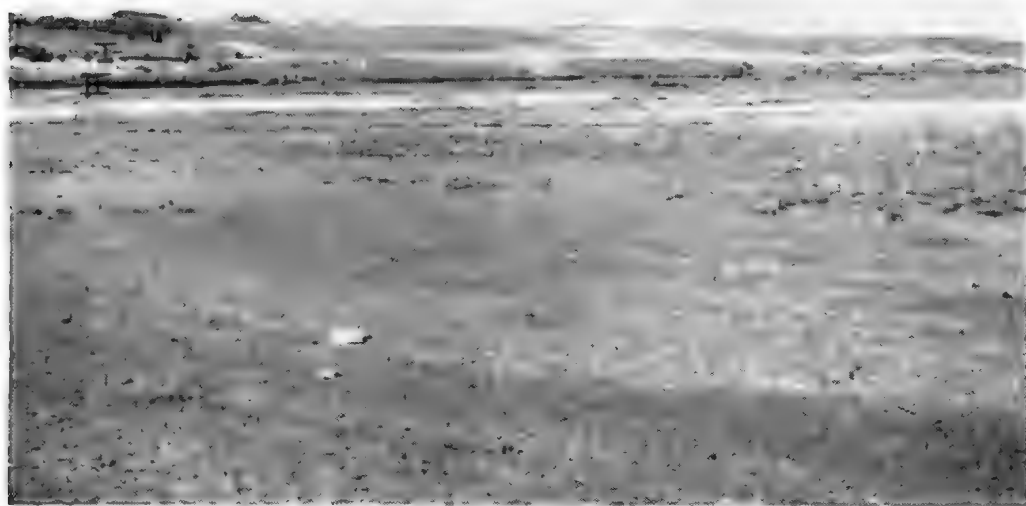
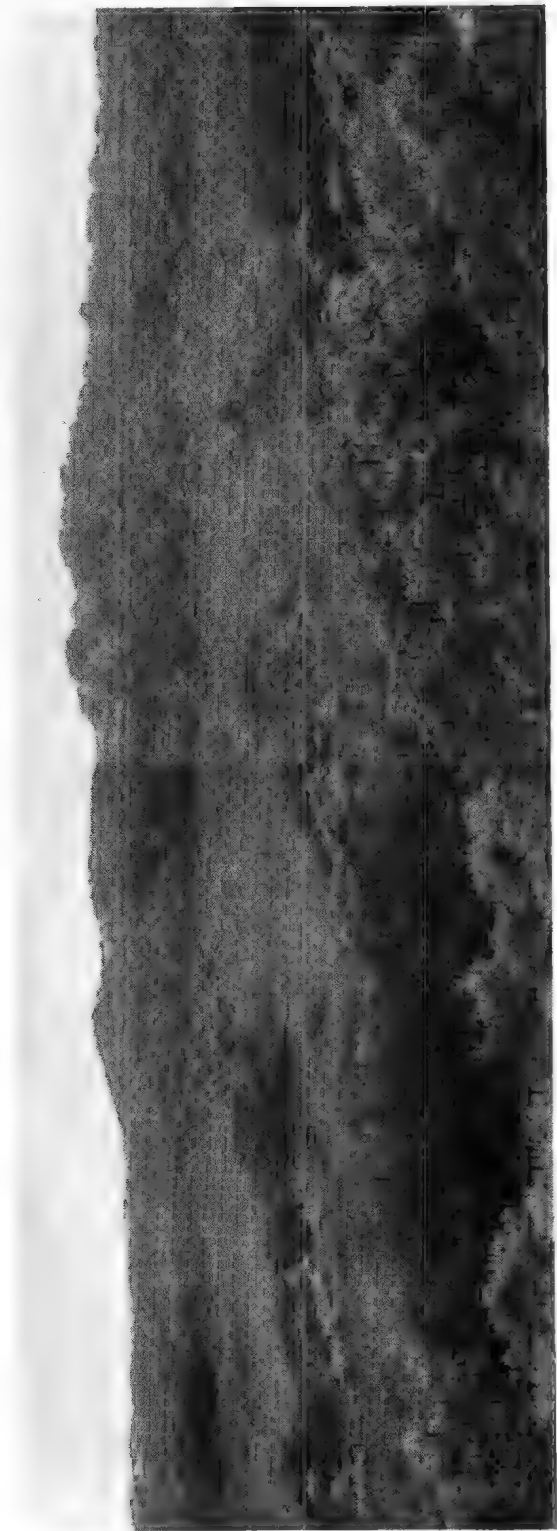


Fig. b.—Stranded shoreline near Coolwa. The toe of the dune (I) is situated above the level of the flats (II) in foreground.





Fig. c.—Detail of depositional creeks in Malcolm combination on Hindmarsh Island. The Murray Mouth just below the photograph is at the south of the island.



Concentric arcs in deep swale on Younghusband Peninsula.



Fig. a.—Detail of possible former Murray Mouth near Coolwa.



Fig. b.—Site of possible former Murray Mouth looking south from Alexandrina Range. Surf visible over low dunes.



Fig. a.—Gently undulating limestone landscape with superimposed dune ridges in Seymour combination



Fig. b.—Two sheets of limestone overlying aeolianite in the Alexandrina combination.  
Grass is growing on top of the lower limestone layer.

# **PLEISTOCENE STRANGLINES OF THE UPPER SOUTH-EAST OF SOUTH AUSTRALIA.**

*BY NORMAN B. TINDALE*

## **Summary**

## PLEISTOCENE STRANDLINES OF THE UPPER SOUTH-EAST OF SOUTH AUSTRALIA.

by NORMAN B. TINDALE

[Read 10 July 1958]

The Pleistocene Terraces of the South-East of South Australia have received much attention because the low slope of the continental shelf has caused the successive strandlines of the Pleistocene and Recent Periods to be spread out over a width of more than 60 miles from the present coastline, enabling detailed study of many minor phases elsewhere obscured by erosion and by compression on a much steeper continental margin. The present writer first contributed to the discussion of this subject in 1933 and again in 1947.

On several journeys between Naracoorte and Keith since 1954 the fore-dune of the Naracoorte Terrace has been closely followed and it was established that it remains on the right of the observer all the way from Naracoorte to Keith, there being a hinge or change of direction from north-north-west to north by east in the vicinity of Darwent Waterhole (Section 7, Hundred of Willalooka), where outcrops of granite, forming low domes at or near former sea level cause local disturbance in the regularity of the dune line. There are other granite outcrops in the Hundred of Marcollat and to the west. At a point three miles east of Keith the Naracoorte Terrace fore-dunes can be seen in section at quarries in the vicinity of Section 51, Hundred of Stirling. The front of the dunes appears to face a vast embayment forming the Keith flats which also at one time seem to have been a lake. The section was demonstrated to Dr. Brian Daily on a brief visit to Keith on 15 February, 1957.

Elevation of Keith R.R. Station on the former sea and lake floor fronting the Naracoorte Range is 101 ft., and the line of railway rises sharply to 210 ft. as it climbs the terrace escarpment towards Brimbago. Naracoorte R.R. Station is at 189 ft. It is situated on a flood fan at the mouth of Naracoorte Creek where it opens on to the old sea floor of Naracoorte times. Away from this alluviated area the interdune flat in the vicinity of Naracoorte may be as low as 120 ft. above sea level, as at Lake Roy about twelve miles north-north-west.

The interpretation placed on the maps of the Geological Survey and outlined in Bulletin 29 of the Mines Department of South Australia delineates the Naracoorte Terrace as running north-westward in a direct continuation of the line of the Terrace at Naracoorte (Sprigg, 1952). The new facts indicate that just beyond the point where their maps terminate there is a marked change in direction.

Some revision may be necessary in our views and in particular there may have been less warping than postulated by Sprigg or it may have affected a smaller area. The writer has formed the opinion, indeed, that the Naracoorte Terrace reported as standing at approximately 145 ft. above present sea level and considered to be down-warped to the north at a tilt of 1.3 ft. to the mile, may be less down-warped than has been suggested, some part of the apparent warping being an expression of differential erosion and sedimentation, and another the diversion of the strandline to the north which alters our interpretation of the positions of the strands. It may be significant that a feeble prior river system has maintained itself across the area ever since this series of strand-

lines commenced to form and the scale of warping does not appear to have induced rejuvenation or marked diversion as a result of the deformation.

Unfortunately, the testing of the area presents difficulties for, although very accurate survey heights are available for the South-East of our State, these become fewer and fail altogether towards the Upper South-East, leaving principally the Railway Survey heights as the basic guide. However, these observations may serve to draw renewed attention to earlier deductions by Tindale (1933, 1947). He considered it possible to trace each Pleistocene strandline across the area broken by granitic domes northward of the Hundreds of Landseer and Peacock, etc., in such a way as to link up with corresponding strandlines at roughly similar heights above sea level, along the Murray River. The Marmion Jabuk Range north of Keith was considered, for example, to be a northward extension of the "earliest Pleistocene dune Range", which he then considered to be the Naracoorte Strand. It can now be re-asserted that it is likely to be part of a complex with a front of Naracoorte and a rear of Hynam strandline features representing an early Inter-Glacial sea margin or margins, perhaps of Milazzian date. The seaward face of the Naracoorte strandline can be traced northward from the vicinity of Keith into the Hundred of Archibald as an extension of the fore-dunes of the Naracoorte strandline. Tindale did not differentiate between the Hynam and Naracoorte Terraces described by Sprigg (1952) and his work must be read with this deficiency in mind.

The dual nature of the Naracoorte Terrace where it turns northward is evident in the south-west corner of the Hundred of Wirrega. It was well illustrated as early as in the May, 1905, edition of the Hundred of Wirrega inch-to-the-mile map. This shows by its delineation of the original vegetational pattern, the Naracoorte strandline in the south-western corner of the Hundred, with Swede Flat compressed between it and what would probably equate with the older Hynam strand. This last named runs north-north-west to east-south-east and is denoted by a belt of dunes, ranging from three and a half to five miles in width, seaward from a line joining Sections 433 and 362.

In passing, it may be noted that Sprigg interpreted the shallowing of the present Coorong lagoon in a southerly direction to be due to the progressive northward down-warping he had postulated. Alderman and Skinner (1957) have shown that precipitation of dolomitic limestone from incoming sea water is occurring and it may well be this activity which was either the chief agent, or at least another factor, in causing the shallowing of the Coorong lagoons southward at a distance from the sea mouth.

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# **COMMUNAL EGG-LAYING IN THE LIZARD LEIOLOPISMA GUICHENOTI (DUMERIL AND BIBRON)**

*BY FRANCIS J. MITCHELL*

## **Summary**

The following observations were made in the Mount Lofty Ranges, South Australia, between 1949 and 1955. It is suggested that the communal nests discovered indicate that this species may form aggregation~ which possess a higher degree of social organisation than that usually credited to reptile communities.

**COMMUNAL EGG-LAYING IN THE LIZARD  
*LEIOLOPISMA GUICHENOTI* (Dumeril and Bibron)**

by FRANCIS J. MITCHELL<sup>\*</sup>

[Read 11 September 1958]

The following observations were made in the Mount Lofty Ranges, South Australia, between 1949 and 1955. It is suggested that the communal nests discovered indicate that this species may form aggregations which possess a higher degree of social organisation than that usually credited to reptile communities.

**OBSERVATIONS**

On 1st May, 1949, at Waitpinga, South Australia, the writer observed several small lizards emerging from the centre of a dead Grass-tree stump (*Xanthorrhoea*) about 12 inches in diameter. On further investigation no fewer than 211 eggs were found closely and uniformly packed in the sawdust-like material which surrounded the hard central core to a depth of about six inches. Of these, 62 had hatched, many of the young being busily engaged digging themselves to the surface, and the majority of the remainder hatched in the laboratory during the ensuing 48 hours. Of the 37 which failed to hatch, 31 contained fully developed embryos which had been dehydrated in transit to the laboratory, and the remaining six, which were much smaller, measuring only  $8 \times 5$  mm. were apparently infertile. Immediately before hatching the eggs measured  $13 \times 8$  mm. Gravid females taken at the same locality between the 7th and 14th November, 1948, each contained three eggs measuring  $7 \times 4$  mm. The size of these eggs as compared with that immediately before hatching indicates considerable assimilation of fluid during development, the volume increasing almost four times. On hatching the lizards measured 41 mm. and they grew without external food to 47-48 mm.

In the hope of being able to observe the actual deposition of the eggs, a further search of the area was made early in December, 1949, but no aggregations of more than four or five individuals were seen, and these small cliques were found to include males. All females examined were still carrying eggs. However, the investigation of potential nesting sites resulted in the discovery of an old nest containing 29 egg-shells. These were inside another *Xanthorrhoea* stump about two miles from the first site. The nest was old, and appeared to have been dug out by a native rat.

Since May, 1949, all casual inquiries received at the South Australian Museum concerning lizard's eggs have been investigated, and this has resulted in the discovery of four more communal nests.

On the 23rd December, 1953, a nest containing 49 eggs measuring  $9 \times 6$  mm. was found in a garden at Stirling, South Australia. The eggs were buried about two inches beneath the surface in loose loamy soil, and were exposed when a small hole was being dug to plant a shrub. The eggs had been freshly laid as the garden was only prepared for planting during the previous week-end. Specimens of *L. guichenoti* were abundant in blackberry bushes adjacent to the garden.

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<sup>\*</sup> Curator of Reptiles, South Australian Museum.

On the 22nd January, 1955, a nest, estimated to contain over 100 eggs measuring approximately 1 cm. long, was found in a heap of vegetable debris lying against the wall of a wooden shed at Aldgate, South Australia. Unfortunately, these eggs were not examined, but using E. R. Waite's "Reptiles and Amphibians of South Australia", the observer, Mr. L. K. Clarke, of Adelaide, South Australia, identified the embryos as *L. metallicum*. The species *metallicum* and *guichenoti* are closely allied and could easily be confused; *L. guichenoti* is the common species in this district.

On the 4th February, 1955, another nest was discovered at Stirling, South Australia. It contained 88 eggs which were found lying side by side in a hollow under a rotting log. The embryos were sufficiently well developed for recognition as *Leiolopisma guichenoti*.

A nest containing "many dozens of eggs" was exposed during the ploughing of a partly cleared paddock near Port Macdonnell, South Australia, during April, 1948. Some of the eggs had hatched, and the finder, Mr. G. H. Tilley of Moorak, South Australia, captured several of the young and preserved them in methylated spirit, together with a dozen unhatched eggs. These specimens were presented to the South Australian Museum in June, 1955, and identified as *L. guichenoti*. (Specimens registered under S.A.M. R 3713.)

#### DISCUSSION.

Sociologists have accepted the greater majority of group behaviour in reptiles as simple tropistic aggregation without a communal aim or internal organisation. Although in the present case the deposition of the eggs has not been directly observed, the data suggests that the gravid females congregate for the purpose of locating a common nesting site. Assuming this to be correct, these lizards must possess a well-developed sense of recognition and be capable of forming communities in which there is distinct coaction between the individuals. Reviewing the observations it is difficult to conceive any other means by which 30-70 female lizards could independently seek out a single nesting site. Furthermore, the nesting sites chosen do not appear to be unique within the general environment. Vegetable debris and dead *Xanthorrhoea* stumps are abundant throughout the sclerophyllous scrub which forms the major habitat of this species in the Mount Lofty Ranges, while the 49 eggs discovered at Stirling in December, 1953, were in the loose soil of a garden plot, all sections of which appeared to be of uniform consistency and humidity.

The present evidence is fragmentary and inconclusive, but it is hoped that the publication of these observations will stimulate the interest of other workers who may be able to undertake a complete field study of this interesting sociological problem.

# **THE NATIVE NAMES AND USES OF PLANTS AT HAAST BLUFF, CENTRAL AUSTRALIA.**

*BY J. B. CLELAND AND NORMAN B. TINDALE*

## **Summary**

A general description is given of the country around Haast Bluff on the northern side of the MacDonnell Ranges, Central Australia, and the native names for over 120 plants are given, together with notes on use, if any, made of them by Aranda and Pintubi natives.

# THE NATIVE NAMES AND USES OF PLANTS AT HAAST BLUFF, CENTRAL AUSTRALIA.

by J. B. CLELAND AND NORMAN B. TINDALE

[Read 11 September 1958]

## SUMMARY

A general description is given of the country around Haast Bluff on the northern side of the MacDonnell Ranges, Central Australia, and the native names for over 120 plants are given, together with notes on use, if any, made of them by Aranda and Pintubi natives.

## INTRODUCTION

The Seventeenth and Eighteenth Anthropological Expeditions organised by the University of Adelaide to study the natives, left Adelaide for Alice Springs on 10th August, 1956, and 15th August, 1957, respectively. These Expeditions were financed by a liberal grant from the Wenner-Gren Corporation for Anthropological Research Incorporated (previously the Viking Fund) of New York, supplemented by substantial assistance from the University of Adelaide and its Board for Anthropological Research and from the South Australian Museum, and by transport facilities granted by the Commonwealth and State Governments.

The members of these Expeditions have been very much indebted to the Minister for the Interior (the Hon. Paul Hasluck), the Administration at Alice Springs and the Department of Native Affairs and its officers for much help and cordial assistance in making their investigations.

On arrival at Alice Springs, the party journey by motor vehicles to Haast Bluff Aboriginal Reserve Station situated 15 miles S.W. from Haast Bluff (of recent geographers), itself about 160 miles due west of Alice Springs and on the Tropic of Capricorn. Here, during a stay of about three weeks in each case, an intensive study of the natives was made by various members of the party. Though the natives were detribalised, the Pintubi people from the Western Australian border area only recently and imperfectly, and were in more or less permanent residence at the Government Station, they still retain much of their knowledge of the natural history of their surroundings and readily supplied names and uses of plants that were shown to them. During our stay, visits were paid to Blanche Towers, Mt. Palmer and Mt. Liebig, to Areonga in the Krichauff Range and to Hermannsburg, to Mt. Wedge Station and Yuendumu, and to the Finke Gorge, at which places some additional plants were gathered.

After the plant was shown to the natives, it was placed in an envelope or paper bag and given a number with the appropriate information. These plants were then crudely pressed and at the same time similar specimens were placed in a botanical press. On return to Adelaide, the plants in the envelopes were identified, and we would like to acknowledge the help we have received from the State Botanist (Dr. H. Eichler); Dr. Consett Davis of the University of New England; Mr. George Chippendale, Botanist to the Animal Industry Division of the Northern Territory Administration; and Mr. David Symon of the Waite Institute. These specimens, seen by the natives, will be presented to the South Australian State Herbarium.

## GENERAL DESCRIPTION OF HAAST BLUFF ABORIGINAL RESERVE

Haast Bluff Reserve, commencing about 150 miles due west of Alice Springs and straddling the Tropic of Capricorn, has an area of about 3,900 square miles. Much of it is low, red sandhill country with a vegetation of its own. We were camped at the eastern end on a mulga plain between the bold mountain masses of the Haast Bluff Range, running west almost to Mt. Liebig, and the distant Mereenie Range, the west end of the MacDonnells, gradually diminishing in height. The northern section of this plain runs west to terminate between the picturesque Blanche Towers and Mt. Palmer on the south and the Haast Bluff continuation on the north.

For descriptive purposes, this terrain can be divided into the plains, the usually dry watercourses, and the mountain masses with their gorges and talus at the base where slopes were thickly covered with gibbers.

## THE MULGA PLAINS

The mulga (*Acacia anura*) on the settlement is of two kinds, one with the usual narrow phyllodes, 3 to 8 cm.  $\times$  1 mm., and the other (var. *latifolia*) with broader glaucous foliage, the phyllodes 4 to 8 cm.  $\times$  5 to 8 mm. n. There was much young mulga 2 to 3 feet high. Some of the young mulgas spread out laterally for 5 feet when only 2 feet high, others tended to grow upwards. Some half grown trees have branches stretching out horizontally, but there seem only the two kinds of adult trees here, in height about 18 to 25 feet. There are many mulga honey-ant holes with rounded raised rims 3 to 4 ins. high, covered with fallen mulga phyllodes, and about 10 to 16 ins. across, with several broad openings to the nest in the centre, which is about 5 ins. wide. These mulga ant holes are only seen in the mulga country and usually close to the bases of the trees. Deep irregular excavations indicate where the natives have been digging out the "honey bags". The flowering of the mulga is probably irregular, depending on the occurrence of rain. A few trees were coming into flower during our stay. No honey could be tasted in the cylindrical spikes of flowers but, as will be mentioned later, a sweet fluid exudes from the gland at the base of the phyllodes when the sap is rising, and a lac scale, when it infests a tree, may result in an abundance of sweet exudate.

At the time of our visit, a sea of a beautiful pink, due to the everlasting, *Helichrysum cassinianum*, spread out under the mulga, to be replaced elsewhere by white from *Helipterum floribundum* (the specific name well deserved), or yellow, from *H. charslayae*. Very abundant and widely spread was the lowly Composite bindi-eye (*Calotis hirsutula*) with its painful spined achenes, tending to get into one's clothing, following on the insignificant flowers. Very abundant also was the Crucifer, *Stenopetalum nutans*, giving a rather dull yellow tinge to the surface when very abundant and having a rather unpleasant smell, resembling the B.B.C. (bromobenzyl chloride) tear gas of the war. In driving through where this was abundant the smell permeated into the vehicle, whereas the fragrance of the pink everlasting was almost confined to a nosegay of it. Another magnificent mass of colour was the dazzling brilliance in places of the yellow flowers of *Senecio gregorii*, a brilliance almost painful to the eye when the sun shone upon an acre or so in an open space. *Bassia convexula*, with five prickles on the fruits, was also very common with some *B. cornishiana* similarly armed.

Witchetty bushes (*Acacia kempeana*) were abundant in places, and especially on light stony rises, Cassia bushes, chiefly *C. eremophila* var. *platypoda*. In addition to the mulga, the plants particularly used by the natives were the

berries of *Solanum ellipticum*, which may be fairly abundant, and the Asclepiad, *Pentstemonis kempeana*, seen occasionally scrambling up a mulga stem.

### THE SAND-RIDGES

Low reddish *Triodia* covered sand-ridges, running east and west, extend north of the Haast Bluff Range towards Mt. Wedge. We passed over 40 miles of these to the east of the Mount between the new aboriginal settlement of Koolpuna and Mt. Wedge Station in part of the range of that name. Picturesque groves of Desert Oaks (*Casuarina decainseana*) grew on many of these. The seedling *Casuarina* becomes first a rather intricately branched shrub. It then grows into a cylindrical small tree like a church-yard cypress, and finally branches out laterally on top into quite an umbrageous head. Another feature of the sand-ridges was the glaucous mallee-like *Eucalyptus gamophylla* with its broad opposite leaves joined together at the stem. On many of the ridges there was little else, but when the soil became more suitable, as towards Mt. Wedge Station, various shrubs appeared between the *Triodia*, and the long siphoned *Nicotiana ingulba*, much sought after by the natives, grew by the side of the track, its fragrant white flowers scenting the air at dusk. Occasional bloodwoods, corkwoods and whitewoods (*Atalaya*) were on the ridges and some yellowish leafless shrubs of *Erocarpus sportea* with a drooping broom-like appearance. Broad-leaved parakeelya (*Calandrinia balonnensis*) found shelter under the *Triodia*. Several belts of *Melaleuca glomerata*, usually associated with watercourses, were passed through and a couple of *Salicornia* (Samphire) flats.

As far as this type of country is concerned, there did not appear to be much of use to the natives. The tobacco was, of course, important. The bloodwood *Eucalypts* might yield some "bloodwood apples" which contain a large juicy female coccid, and the witchetty lishes (*Acacia kempeana*) could contain the grubs of that name in their roots. The *Triodia* near the north edge of this country seemed larger, more flexible and less prickly than that in the ridges, and "Nosepeg", the Pintubi native with us, pointed out the red sand-encrusted resinous tunnels on some of the leaves protecting the underlying Coccid from which *Triodia* (usually spoken of as 'spinifex') gum is obtained.

### THE PLAIN BETWEEN THE HAAST BLUFF AND MEREENIE RANGES

The country for the 27 miles to Blanche Towers is nearly flat. There are some belts of dense mulga and many patches of *Triodia* in heavy sandy loam, sometimes quite open with occasional tall bushes of *Grevillea punicifolia*, *Eucalyptus papuana*, and bloodwood or *Euc. gamophylla*. Towards the western end were many fine Desert Kurrajongs with tall rounded boles and spreading branches high up, growing in sandy loam. These were succeeded by Desert Oaks, the half-grown trees conicocylindrical. Often flat, very hard termitaria, occurred amongst the *Triodia* and tall ones, three to four feet and flat-sided, amongst the mulga.

### THE WATERCOURSES

The watercourses have a vegetation of their own. In most of them, the Red Gum (*Eucalyptus camaldulensis*) with bluntly conical rather than rostrate opercula, is to be found as well as *Solanums*, *Crotalaria dissitiflora*, Coral Trees (*Erythrina vespertilio*), the fragrant *Prostanthera striatiflora*, sedges, grasses, Cassias and other shrubs.



## THE MOUNTAINS AND HILLS

The mountains are covered with scattered *Triodia* tufts where the slope permits them to grow. On the tops, as at Mt. Liebig, *Acacias* and other shrubs may be found not seen lower down. In the gorges grow Native Hop-bushes (*Dodonaea petiolaris*), the Native Currant (*Carissa brownii*), *Grevillea wickhami*, tufts of scented grass, *Solanums*, and many other under-shrubs and herbs. Native pines (*Callitris glauca*) are uncommon here. At Taliperta Spring near Mt. Palmer, a permanent spring under the shadow of a ledge has given for many centuries a shower-bath which has enabled something like five species of fern to survive desiccation.

*Triodia*-covered rocky outliers of the Haast Bluff Range near the settlement had scattered small trees of *Eucalyptus papuanu* and *Euc. gamophylla* (shrubby), two species of *Cassia*, *Acacia notabilis*, *Ac. patens*, a Lycopodium-like *Acacia*, a viscid species of *Acacia* and one with very long phyllodes, and as more lowly plants, scattered *Goodenia ruvenellii*, an *Indigofera*, *Kerandrinia* with its blue flowers, *Grevillea wickhami*, a daisy (*Minuaria* ?) and the fern *Notholaena*.

In such types of country, the original Aranda, Kukatja and Jumu natives and the intruding Pintubi of later years, successfully obtained the necessities of tribal life. It is the object of this paper to record the names and uses of the plants that were available to them. The uses comprise food plants, such as berries, other fruits, cresses, tubers, roots, grains, honey, gall-insects, etc.; the Native Tobaccos; woods for weapons and utensils; and plants used for adornment and other purposes.

There are probably more than 1,200 species of vascular plants in Central Australia between 20° S. (passing through Tanami and well south of Tennant Creek) and 26° S. at the South Australian border. One of us (J.B.C.) has himself collected more than 530 separate species. During the 1956 Expedition, 133 specimens comprising 110 species of vascular plants and two fungi, were submitted to the natives. During the 1956 Expedition, the number of specimens was 165, consisting of 132 species. Some of these species were the same as were submitted on the first occasion and this served as a check on the native names that were given then. The total number of species including 3 varieties shown to the natives was 191. On a rough estimate one might say that about one-sixth of the vascular plants of the area were shown to the natives. This list must comprise nearly all the species of economic use to them. There must be a considerable number of small ephemeral plants that come up after rain which are of no consequence to them. Of the total of 191 species, 55 had no name or use, and a number of others had a name but were not used.

The uses of the plants can be placed under the following headings:—

**Grains of grasses, winnowed and made into a paste:**

*Tragus racemosus*, *Brachiaria piligera*, *Panicum decompositum*, *Eragrostis eriopoda*, *E. dielsii*, *Dactyloctenium radicans*.

**Other seeds ground into a paste:**

*Chenopodium rhadinostachyum*, *Portulaca oleracea*, *Acacia ligulata*, *Acacia patens*, *Brachychiton gregorii* (Desert Kurrajong).

**Seeds eaten:**

*Casuarina decaisneana*.

**Currant-like berries:**

*Carissa brownii*, *Plectronia latifolia*.

**Tomato-like fruits:**

*Solanum nemophilum*, *S. coactiliferum*, *S. ellipticum*, *S. eremophilum*, *S. diversiflorum*, *S. philomoides*.

**Other fruits:**

*Ficus platypoda*, *Eucarya acuminata*, *Loranthus murrayi*, *Enchylaena tomentosa*, *Capparis mitchellii* (native orange).

**Leaves and seed-vessels eaten:**

*Marsdenia australis* (leaves and young banana-shaped fruits), *Cynanchum floribundum* (leaves and young fruits), *Pentstemonis kempeana* (leaves and follicles).

**Roots eaten:**

*Boerhaavia diffusa*, *Portulaca oleracea*, *Vigna lanceolata*.

**Leaves steamed:**

*Lepidium muellert-ferdinandi*.

**Flowers sucked for honey:**

*Hakea ivoryi* (corkwood), *Eucalyptus terminalis* (bloodwood).

**Ash used with Pituri:**

*Acacia* sp.

**Tobacco leaves chewed:**

*Nicotiana glauca*, *N. ingulba*.

**Plants used as medicine by steaming:**

Though the idea may have derived from contact with Europeans who doubtless imputed medicinal qualities when there was an aromatic scent, it is probably original. Steaming is used in all parts of Australia and steaming-oven stones occur in deposits from the Pirriian Culture onwards, a period of at least 4,000 years.

*Prostanthera striatiflora*, *Stemodia viscosa*, *Eremophila gilesii*.

**Yielding adhesives:**

*Triodia basedowii*, *Xanthorrhoea thorntoni*.

Apart from these vegetable sources of food, whose food values can be ascertained if necessary in years to come, the natives obtained animal foods in the shape of flesh (of marsupials, dingoes, small rodents, birds, lizards and snakes), of birds' eggs and of insects (witchetty grubs from moths and beetles, termites and their eggs, grasshoppers and locusts, female coccids in galls on the bloodwood, and lerp), and honey from the mulga honey-ants and native bees.

**THE SOLANUMS OF CENTRAL AUSTRALIA**

The Solanums of Australia are of considerable interest as being a source of food for the aborigines. In fact, in Central Australia one species, *Solanum ellipticum*, is of real importance as it is said to furnish small edible green tomatoes all the year round and is a widely distributed species and with reasonable assiduity in the search for it, numerous enough to furnish food on most occasions and situations.

In South Australia, 26 species of *Solanum* are known, *S. lasiophyllum* having been found in the Tomkinson Ranges too late for inclusion in Black's Flora, Part IV, Second Edition, where the names of 25 appear. Of these five are introduced species, *S. triflorum*, *S. giganteum*, *S. elaeagnifolium*, *S. sodomaeum* and *S. rostratum*, none of which are edible.

Ewart and Davies in "The Flora of the Northern Territory" record 19 species with an additional one for North Australia, of which 9 occur in South

Australia. The other eleven are mostly only recorded from the northern end of the Territory.

During the two expeditions to Haast Bluff Reserve, at least eleven species of *Solanum* were collected, five of these being found within a few yards of each other in wash-aways leading into a creek.

Of these, five species had few prickles and six were furnished with abundant spines. Some of the latter supplied an important item in the diet of the nomadic natives, and others were of no account in their ecology. The aborigines readily recognise each species and have names for them, but to European eyes the distinction was often difficult. The following points we found useful in recognising the different species of very prickly *Solanums*.

*Leaves entire*

*Solanum ellipticum*. Semi-prostrate to scrambling with purplish tints on the young foliage. The spherical green fruits marbled with white are hidden, so that one turns the foliage over with one's foot to pick the edible berries. The prickles are not very aggressive so that one can handle the bush without being severely punished. There are purple spines on the stems and calyx and some pale ones on the petioles and even midribs but not elsewhere on the leaves.

*Solanum ellipticum* var. Mr. J. M. Black referred specimens like this to *S. eremophilum*, but Mr. R. V. Smith, of the National Herbarium of Victoria, says our plants are definitely not *S. eremophilum*. This has smaller leaves than *S. ellipticum* and lacks the purple tints. It is more or less prostrate and the prickles are not aggressive. The edible fruit is like that of *S. ellipticum*.

*Solanum quadriloculatum*. This is an upright species abundantly furnished with spines which make it difficult to collect specimens. The leaves are thicker and broader than in *S. ellipticum*, but acute like them. The young foliage may be purplish. The berries are more numerous and easily seen, usually not quite round but somewhat pentagonal, showing five bulges, green becoming suffused with purplish tints before becoming hard and pale. Fruit inedible, four-celled.

*Leaves pinnate-lobed or pinnatifid*

*Solanum petrophilum*. This resembles *S. quadriloculatum* but the leaves are shortly lobed. The berry is hard and inedible. The prickles are very aggressive. The calyx lobes are narrow, acuminate, with prominent keels.

*Solanum melanospermum*. Mr. R. V. Smith considers our plants as probably referable to this species. They agree with the type in leaf lobing, tomentum, spines, etc. Unfortunately, he adds that the type shows no flowers. He says it is not referable to *S. diversiflorum* as we had suggested. Has deeply lobed leaves and calyx lobes narrow and acuminate without prominent keels. The fruit is an inch in diameter, pale yellowish green and edible.

*Solanum* sp. aff. with *S. phlomoides*, A. Cunn. and *S. melanospermum*, F. Muell. (R. V. Smith). Has the remains of a large calyx still on the reflexed stem. The calyx lobes are broad and there are pale prickles on the stems and calyx and a few on the leaf veins. The large fruit is edible.

*Solanum ferocissimum*. Upright, about a foot high, with small pale flowers and narrow leaves hastate or cordate at the base, grew on the banks of a creek. Fruits red and not eaten.

*Solanum centrale* and *S. orbiculatum*. Were growing in proximity to each other. The former has a rust-coloured tomentum with ovate to ovate-oblong leaves and calyx segments oblong-linear. It was not found in fruit which Black described as ovoid, yellow, succulent and edible.

*Solanum orbiculatum*. Has thicker oblong leaves which Black described as sinuate-lobed, with a hairy calyx whose lobes are ovate-lanceolate, and yellow globular berries.

*Solanum* sp. A small *Solanum*, only a few inches high, with an elongated berry was found on an open plain north of Mt. Hay.

*Solanum coactiliferum*. Petals 4, edible sperical yellow fruit. Mt. Wedge Station and sandy rises on Haast Bluff Reserve.

*Solanum esuriale*. With five petals and yellow edible fruit has also been found in Central Australia.

### THE NATIVE NAMES

The native names here recorded in several tribal dialects were transcribed by the one hand from information supplied by different informants. It was not convenient to keep a record of the name of each informant since it was sometimes necessary to refer the specimen to a whole gathering of interested on-lookers before a decision was made. In all cases, unless specified to the contrary, the words were spoken by a man of the tribe concerned and not repeated from hearsay by one of another tribe. Where marked variations in pronunciation were noted they are indicated. Principal differences are in the vowel sounds, but there are also some interesting variations in stress. Some minor differences may be ascribed to the modern reaction between the Aranda language as used in formal mission teaching and the several versions of it being acquired by the Western Desert tribes people as they come into the area. The Kukatja (Loritja) have been closely associated for at least three generations with the Aranda, the Jumu for two generations and the Ngalia and Pintubi only since about 1932. Since the break between Aranda-like languages and the Western Desert ones (Pitjandjara, Kukatja, Pintubi, etc.) is one of the more conspicuous ones in Australia it will be of interest to have data enabling a clear-cut distinction to be drawn between the plant names used east and west of this linguistic boundary. The names are written in the system adopted by a Committee at the University of Adelaide in 1932. A convenient exposition may be found in Volume 64 of these Transactions, at page 147.

In the following list of plants, if the species concerned appears in Black's Flora of South Australia, the author's name is not given.

### FILICALES

*Cheilanthes tenuifolia* (81b). No name; grows on sides of creeks.

*Notholaena brownii* (44b). No name; grows only near water in gorges.

*Marsilea*, probably *M. hirsuta* (55b) Nardoo. No name; animal food, no good for man.

### PINACEAE

*Callitris glauca* (15a). Native Pine. kulilpuru, Pintubi. wanḱarti, Ngalia. 'ulkḱarta and 'ilukwa, Aranda. Not used; appreciated only for the shade it casts.

### GRAMINEAE

*Imperata* ? (18a and 99a). talbalbi, Ngalia. lalbulara, Aranda. A bladey grass found only at springs such as Ulanbaura where there is a permanent swamp. The leaves agree with those of *Imperata cylindrica* var. at Encounter Bay.

*Dicanthium sericeum* (107b and 108b). 'tjawila, Pintubi; 'nam:a, Aranda (Generic terms).

*Bothriochloa ewartiana* (130a). No native name, "only a grass".

*Cymbopogon bombycinus* (68a). No native name.

- Themeda australis* (39a). 'eria, Pintubi. 'kalbulbi, Ngalia. 'ara 'ara, Aranda. It is used to stop the splash of water in wooden dishes while they are being carried on women's heads.
- Tragus australianus* (76a). i:ka, Pintubi. 'punda'ro, Ngalia. jaka, Aranda. A prickly grass; it provides 'mi, i.e. a damper which is made from the seed by milling between stones.
- Neurachne mitchelliana* (121a, 93b). 'mana, Pintubi. It has no native use.
- Brachiaria piligera* (129a, 135a). 'mana, Pintubi. 'etuta, 'indaluruka, Aranda. The grass seed is milled with water between stones and cooked as a damper.
- Digitaria unimophila* (117a). Has no native name, "only a grass".
- Panicum decompositum* (107a, 75b). il'tja:dua, Aranda. eltja:tua, 'jalka:ra, Pintubi. Yields a good grass-seed food; ground with water between mill-stones and cooked as a damper ('juma, Pintubi).
- Pennisetum ciliare* L. (*P. cenchroides* Pers.) = *Cenchrus pennisetiformis* Hochst et Steud. (138b). Buffle grass. Only a grass, a stranger.
- Zygochloa (Spinifex) paradoxa* (160b). Only a grass, 'along sandhill'.
- Aristida browniana* (118a). Has no native name, "only a grass".
- Aristida arenaria* (96a). 'okari, Pintubi. 'endalkura, Aranda. Grass eaten by animals, a prickly grass.
- Aristida arenaria* (71b). 'ipiri, Pintubi. 'jawila, Ngalia. 'endurukura, Aranda. Has sharp 'spined heads'.
- Aristida nitidula* (164b). 'awila, jawila, Pintubi. 'endurukuru, Aranda. No use.
- Enneapogon polyphyllus* (81a). 'je:pari, Pintubi. 'man:a, Ngalia. 'uam:a, W. Aranda dialect. 'taruka, E. Aranda dialect. Only a grass, not a food.
- Enneapogon clelandii* (5a, 149b). Has no native name and is of no use. Only a grass for cattle, horses and sheep.
- Enneapogon* sp. (54a). Drumstick grass. Has no native name, "only a grass".
- Danthonia bipartita* (78a, 123a, 155b). Only a grass, of no use except to animals.
- Triraphis mollis* (105a). 'endurukura, Aranda. When the seed is taken in while drinking water it causes an irritation to the throat, and is much disliked. The seed pierces the gums of horses' mouths causing an inflammation.
- Triodia pungens* (21a). 'undia, Pintubi. 'ju:ta, Aranda. This species is said not to yield a gum; the *Triodia* from which the valuable native gum is obtained is said to "look greasy".
- Triodia basedowii* with gum (101b). tjanbi, Pintubi. undia, Kukatja. 'ju:ta, Aranda. Flowers and seed are animal food.
- Eragrostis eriopoda* (71a, 133b). wanjumu, Pintubi. in'tjira, n'djira, Aranda. The seed is gathered, milled with water between stones and cooked as a damper.
- Eragrostis dielsii* (150b). 'intjirintjira, Aranda. Provides seed for milling.
- Chloris acicularis* (23a). No native name, "only a food for animals".
- Dactyloctenium radulans* (80a). 'purundjari, Pintubi. 'inda'hruka, Aranda. Seed is used in the same manner as that of *Eragrostis eriopoda*. Is considered to be a good food.

## CYPERACEAE

- Cyperus xerophilus* (35a). 'laripulara, Aranda. A mark of water country.
- Cyperus* sp. (54b). an'garan'gara, Aranda. Found near springs, sign of water.
- Fimbristylis nutans* (Retz.) Vahl. (31a). 'ju:lumburu, Ngalia. 'laribulara, Aranda. Not used. A sedge at Ulambaura, a permanent spring. The Ngalia name for the spring is based on the presence of reeds. An Aranda name for the spring is Paura.

*Scirpus litoralis* (158b). 'an̄karaṅka, Pintubi. No name in Aranda. Lives in spring water.

## LILIACEAE

*Xanthorrhoea thortoni* (48a). alun̄kuru, Ngalia. alun̄kuru, Aranda. It grows in the sandhills in the MacDonnell Ranges and on the plains to the South. Aborigines have never seen it to the north of the Ranges. It is of economic importance to them because the resinous excretion from it is made into the gum which provides the most highly-sought-after form of hafting medium for stones set in the ends of spearthrowers. This gum is known as 'pal:a, Ngalia; 'tjalana, Aranda.

## CASUARINACEAE

*Casuarina decaisneana* (53a). 'korukara, Pintubi. 'karukara, Ngalia. arkapa, Aranda. "There is good food in the seeds; pick out kernels, chew them when green, they taste like milk."

## MORACEAE

*Ficus platypoda* (50a). 'ili, Pintubi. 'witjiriki, Ngalia. 'tjuruka, Aranda. Figs.

## ULMACEAE

*Trema aspera* (45b). Only a tree, no name. Grows only near water in gorges.

## URTICACEAE

*Parietaria debilis* (159b) (under rocks). "Only a flower, near water." [Does not grow near water.]

## PROTEACEAE

*Hakea lorea* (143b). Corkwood. pirdwa, Kukatja. an'tjuia, n'kwala, ndjujamba, Aranda. Flowers yield sugar by steeping in water.

*Hakea ivoryi* (8a, 87a, and 124a). Corkwood. 'piriwa, Pintubi. bi:ru, Kukatja. n'djuia, Aranda. When emus eat n'djuia flowers they are stupefied and cannot run and thus easily killed; it flowers in summer. Corkwood flowers are steeped to get a black, sweet liquid. Use the bark, charred, to rub on the breasts of women when the child has a sore tongue.

*Hakea leucoptera* (126a, 85b). 'marawakara, 'marawakal, Pintubi. ilbunga, Aranda. Used for making hut shelters; not used as root source for water as is the case further south.

*Grevillea juncifolia* (92b). 'jultukun, Pintubi. 'kalin'kalin̄ba, Aranda.

*Grevillea striata* (70b). ildeilba, Pintubi. ildi:lba, Ngalia. ildi:lba, Aranda.

*Grevillea wickhami* (63a). 'ljaka, Aranda. No use.

## SANTALACEAE

*Exocarpus spurtea* (43a). 'wilpia, Pintubi. 'winbaruru, Ngalia. 'itjartitjarda, Aranda. No use; it is plentiful on Mt. Wedge and in the sandhill country.

*Eucarya acuminata* (62a). Native peach. 'majarta, Pintubi (occurs in country to the south-west). 'majarta, Kukatja. 'malba, Aranda. Some trees grow near Alalpa, where it is a big tree; it is said by the natives to grow commonly along the southern side of the MacDonnell Ranges.

*Santalum lanceolatum* (23b). kandurano, Pintubi. kandurana, Kukatja. 'kaluda, Aranda.

## LORANTHIACEAE

*Loranthus murrayi* (on *Acacia rheticocarpa* and *Acacia aneura*) (102a, 27b, 104b, 119b). 'nantja, Pintubi. 'mi:puru'pa, Pintubi. 'tjanguina, tjankanu, Aranda. Fruit orange or red coloured, "eaten as a plum, very nice".



- Loranthus exocarpi* (on mulga) (91b). 'nantja, Pintubi. Edible fruits.  
*Loranthus gibberulus* (on *Grevillea wickhami* and *Grevillea striata*, beefwood) (20b, 86b). 'mi:purupa, Pintubi. 'tjan'ga, Aranda. Bird food only.  
*Loranthus miqueliana* (on *Euc. gamophylla*) (24b). The mallee (*Euc.*) = 'warilja, Kukatja. lalba, Aranda. The mistletoe = im:ara, Kukatja. im:ara, Aranda.  
*Loranthus maidenii* (on mulga) (59a, 35b). etjitja (mulga), 'tjan'ga (*Loranthus*), Aranda. Children eat the sticky fruits in play; birds eat the fruits. It has no further use other than as attracting birds which may be killed by throwing a boomerang or stones.

## CHENOPODIACEAE

- Rhagodia spinescens* (89a, 38b). 'bulam'bula, Aranda. Used as red paint for the face; the ripe fruits are red.  
*Rhagodia nutans* (1a, 37b, 118b). 'iria, 'eria, Aranda. Emu food; only a bush; no use.  
*Chenopodium cristatum* (74b). 'tjilka, Pintubi. 'madara'madara, Aranda. Food for kangaroo, emu and stock.  
*Chenopodium rhadinostrachyum* (13a). 'induku, Aranda. The black seed obtained from it is soaked and when swelled with water rubbed between stones to make a damper.  
*Atriplex nummularium* (101a). Salthush. 'eria, Aranda. As an animal food it attracts and concentrates game for hunters.  
*Atriplex elaeagnifolium* (69a). No name. Only cattle, goat and sheep food.  
*Bassia sclerolaenoides* (69b). tjilka, Pintubi. 'No good; only a flower.'  
*Bassia quinquecuspidata* (94b). marawakalba, Kukatja. jeltja 'ta:ndina, Aranda. The Kukatja name means literally 'hand piercer', it is often used as a generic name for spiny plants. No use.  
*Kochia encalyptoides* (163b). Only a bush.  
*Salsola kali* (65a, 22b). tjilka:la, Kukatja. 'elkala, ilkala, Aranda. Only an animal food.  
*Encalypta tomentosa* (7a, 90a, 91a). 'jewete'wete, Ngalia. indi:ndia, Aranda. The red fruits are soaked in water and the liquid drunk like tea; it is very sweet; use a 'taria, an especially shaped pitji (dish), for its preparation.

## AMARANTHACEAE

- Ptilotus nobilis* (14a). No native name, only a flower.  
*Gomphrena brownii* (63b). Only a flower.  
*Alternanthera nodiflora* (134a). Has no native name; no use, only a flower.

## NYCTAGINACEAE

- Boerhaavia diffusa* (55a). 'waipi, Kukatja. 'iap:u or 'jaiipa, Aranda. Has a long parsnip-like root; food.

## PORTULACACEAE

- Portulaca oleracea* (83a). 'wakati, Pintubi. 'ngotjika, Aranda. Food; eat the black seed; the root is also eaten.  
*Calandrinia balonensis* (17a, 52a, 16b). Parakeelya. 'parkilja, 'tjonni tending to 'shonni, Pintubi. partandjarupa, Ngalia. 'tjungi, Kukatja. ilknoalia, knilja, gamba, Aranda.

## CAPPARIDACEAE

- Capparis mitchellii* (92a, 2b, 129b). Wild orange. 'ulpundjatu, Pintubi. 'omboltja:di, 'umbutja:di, Kukatja. bultja:ta, m'bultjeda, m'bartjada, Aranda. Eat the fruit, "no seed, very sweet".



*Capparis spinosa* (145b). 'uraniqi, Pintubi. 'aratnaqa, a'ro:tnaqa, Aranda. Yield a fruit which is eaten when ripe.

### PHYTOLACCACEAE

*Codonocarpus cotinifolius* (68b, 89b). 'kanduraŋu, Pintubi. 'kaluta, kaludi, kaluda, Aranda. Grubs 'mako 'kaluda, Kukatja, found on the roots are eaten.

### CRUCIFERAE

*Stenopetalum nutans* (70a, 26b). 'enmart'enmarta, Aranda. Emu food.

*Stenopetalum lineare* (84a, 100b). 'enmarta, Pintubi. enmarta, 'murti murta, Aranda. "Too 'strong'; only fit for emus, makes you giddy if you try to eat it."

*Lepidium rotundum* (97a, 116a, 116b). 'enmarta, Pintubi. jurtaju:ta, Ngalia and Pintubi. 'enmatua, Aranda. Emu food. The same name is applied to *Glossogyne* (Compositae). Aranda eat it after steaming; Pintubi do not use the steaming method of cooking greens and make no use of 'enmarta.

*Lepidium oxytrichum* (105b). 'enmarta, Pintubi. 'enmarta, Aranda. Emus eat it. Aranda steam it.

*Lepidium muelleri-ferdinandi* (95a, 98a, 29b). enmota, Pintubi. inmutu, Kukatja. 'inmorta, enmarta, enmatua, Aranda. Plant steamed in a hole with hot stones by the Aranda; the plants are enclosed in a covering of *Zygophyllum* plants ('Ijawuljawa). The steamed green is stripped off the stems and eaten; the stems are then pounded to a meal and also eaten. When stones are not available it is laid on heated ground on top of wet grass, covered by more grass, then with colder sand. Enough heat is sealed in to cook the food. The aborigines strip off the leaves and eat them, throwing away the stems. A big heap is cooked and all eat together.

### PITTOSPORACEAE

*Pittosporum phillyreoides* (102b). wanukutu, Pintubi. 'mara mara, Kukatja. knauta, Aranda. Provides shade only; no other use.

### ROSACEAE

*Stylobasium spathulatum* (97b). 'tulpulpa, Pintubi.

### LEGUMINOSAE

*Acacia ligulata* (27a). Broad leaf wattle. 'wardaruka, Ngalia. 'itjiruka, Aranda. Seeds eaten. Grows at Ulambaura Spring.

*Acacia ligulata*, a form (on stony hill) (79b, 120b). wardaruka, wa:daruka, Pintubi and Kukatja. i:'turuka, 'i:tjaruka, Aranda. Not used.

*Acacia notabilis* (as hitherto identified but really a new species) (31b). 'itjiruka, Aranda. Not used except as dry wood for fires; just like ironwood, very good for fires.

*Acacia patens* (115b). 'luba'luba, Aranda. Seed eaten, ground on a stone to a meal; it makes a bean soup with water.

*Acacia strongylophylla* (43b). Only flower, grows on the ranges.

*Acacia lycopodiifolia* (77b). No native name.

*Acacia coriacea* var. *angustior* (83b). banguna, Pintubi. panjkuna, Ngalia. 'panku:na, Aranda. Multi-striate phyllodes, 20 cm. × 4 mm. Yellow branches, grows on rocky hills. Use ashes for drawing with. Freshly burned ashes of the leaves are mixed with native tobacco (mingulba) when making a chewing quid.

*Acacia ancura* (15b, 72b). Mulga at the settlement, Haast Bluff Reserve. 'wanari, Pintubi, Ngalia. i:'titja, 'u:titja, Aranda.

Lac Scale (*Austrotachardia acaciae*, Maskell) on *Acacia ancura* (131b). 'lutandja, Aranda. Lerp scale and honey exudate on the phyllodes of the mulga. According to native belief 'kapada:da, the larva of a Geometrid moth, is the leader (inkata) of the honey ant (jeramba) which gathers this honey.

Honey on *Acacia ancura* (130b). lutandji, Aranda. A particular source of mulga sugar is from the exudate of glands in the young mulga tips themselves. Aborigines showed us that when viewed against the light the tips bore gleaming beads of honey-like sap at the bases of the phyllodes. These glistening particles ('lutandja, Aranda) are supposed in native zoology to become larger, form together along the stems and become the lerp scales which yield sugar. The larva of a Geometrid moth of the mulga (species not yet identified, but close to *Amelora*) occurs as a larva in many hundreds on mulga trees; when the trees are disturbed the larvae lower themselves on long silken strands so that the whole tree appears decorated with them; the larva is called 'kapada:da, Aranda. It is considered to be the leader or inkata of the 'jeramba, Aranda (honey ant) and causes it all to happen. Honey ants gather and take the honey below ground to form the honey ant "bags". The 'kapada:da (Aranda) is known also as njanda (Aranda) and as pun:a parutji:ta, Kukatja.

The lerp scales grow large and fall off on the ground whence they may be gathered or are stripped from the twigs and soaked in water to make a drink. Lerps are also eaten off by drawing the twigs through the mouth. One of us (N.B.T.) some years ago, observed the extensive use of this lerp scale in the Mann Range where the women's lips were bleeding and sore from the continual rubbing of them along the rough twigs. In 1957 he found that a family group at Lightning Rocks, Western Australia, had been living in this way for a week almost solely on lerp sugar. The amount of food available on these twigs is surprisingly great and they can be seen to be literally running with honey-dew.

*Acacia ancura* var. *lufifolia* (73b, 143b). Blue mulga. 'lelele, Pintubi. ljalpiljaro, Ngalia. i:'titja il'paljata, Aranda. Seed eaten. Honey-dew at the base of the phyllodes, 'muni in'da:na, Aranda. Seeds gathered, parched and ground for meal.

*Acacia holosericea* (28a, 125b). 'kalkadi, Pintubi. 'intjira, Aranda. No use. A wattle growing around Ulambuara Spring. The same species in 1957 on a rocky hill with lac insects (*Austrotachardia acaciae* Maskell). 'nkwala'i:titja, Aranda. Eat the sweet scale (mako karuko). The jeramba or honey ants sometimes gather honey from these scales. Tree is named 'papa same word as for dog.

*Acacia brachystachya* (106a, 82b) (probably) a mulga. wanika, wanari, Ngalia. 'i:titja, Aranda. The ashes from freshly burned phyllodes are chewed with pitjiri. Shrub not in flower or fruit when collected. The phyllodes are 9.0 cm. to 11.5 cm. long and agree with this species, but it may be merely a long phyllode form of *A. ancura*.

*Acacia farnesiana* (154b). i'lakwa = i'lokwa, Aranda. From the flower comes a seed which is eaten by parching and milling.

*Acacia monticola*, J. M. Black (80b). On rocky hill. No native name. Lacerated bark, several nerves, much reticulation.

*Cassia sophera* (146h). 'madara'madara, Aranda. Good medicine. Steep in warm water, wash face with liquid and inhale the steam from the dish.

- Cassia pleurocarpa* (4b, 120b). 'kalpukalpu, kalbirkalbir, Pintubi. 'leilara, 'lelara, Aranda. Emu food only.
- Cassia desolata* (95b). 'pundi, Pintubi. 'inkutin'kuta, Aranda. For decoration only.
- Cassia eremophila* (40a, 33b). 'aribi, pundi, Pintubi. 'pundi, Kukatja. 'wari, Ngalia. 'pundi, 'punda, Aranda. Has no important use; only a flower, used, mainly because of its soft foliage, for brushing off flies.
- Cassia eremophila* var. *platypoda* (114a, 65b). 'pundi, Pintubi, 'punda, Aranda.
- Cassia artemesioides* (22a, 58a, 30b, 78b). pundi, Pintubi. pundi, Ngalia. 'punda'punda, inkurtaankurta, Aranda. The flowers are used for decoration, being inserted in the head band as a fringe falling over the brow.
- Brachysema chambersi* (161b). omba. Sugar obtained from the flower called 'ŋkwalā omba, Aranda.
- Crotalaria dissitiflora* (41b). Only flower; no name.
- Indigofera brevidens* (126b). No name.
- Indigofera basedowii* (127b). "Too shrivelled for identification", "might be 'pundi".
- Psoralea* (148b). Pea. 'woraka'lilja, Aranda. No use.
- Suaresona flavocarinata* (151b). Only a flower, animals eat it.
- Vigna lanceolata* (19a). 'papurti, Ngalia. 'latja, Aranda. The root of this plant or the one for which the aboriginal informant mistook the leaf is eaten; it is supposed to have a large tuber like a sweet potato.

## GERANIACEAE

- Erodium cygnorum* (82a, 40b, 64b). Has no native name and no use is made of it.

## OXALIDACEAE

- Oxalis corniculata* (34a). Native sour sob. 'elkart'ilkarta, Aranda. Wallaby food only.

## ZYGOPHYLLACEAE

- Zygophyllum tesquorum* (53b). 'ilk'ŋwalja, Aranda. Animal food only.
- Tribulus terrestris* (75a). tjilka:la, Pintubi and Ngalia. 'jaka, Aranda. A prickly plant which causes trouble by injuring feet.

## EUPHORBIACEAE

- Euphorbia drummondii* (52b). ma'dara'madara, Aranda. Animal food.
- Euphorbia wheeleri* (57b). ma'daramadara, Aranda. Bullock and horse food only.
- Euphorbia chutioides* (6a). 'notanoto, Ngalia. 'kwarakelilja, Aranda. Although it has a name, neither the plant nor its milky sap has any use.
- Phyllanthus* sp. (36a). tjilkatjilkarupa, Pintubi. 'pojor'pojorupa, Ngalia. Not used, and is poisonous.

## STACKHOUSIACEAE

- Stackhousia muricata* (140b). Only animal food, no name.

## SAPINDACEAE

- Atalaya hemiglaucā* (25b, 87b). 'wanukutar, Pintubi. ilbara, ilpa'ra, Aranda. Shade tree only.
- Heterodendron oleifolium* (115b). wanjikutu, Pintubi. knjira, Aranda.
- Diplopeltis stuartii* (84b). Only a flower.
- Dodonaea petiolaris* (47a). njalpilinj, Pintubi. anjilinu, Ngalia. walukara, Kukatja. 'ilpa'manda, Aranda. No special use except as a shade tree.

## RHAMNACEAE

*Ventilago viminalis*, Supple Jack (113a, 34b). k'njira, aknjira, Aranda. Kangaroo and euro shade tree. A big tree and it gives good shade. When it has a hollow stem find wild honey (ultamba) in it.

## MALVACEAE

*Malvastrum spicatum* (112a). Has no native name, only noticed by them because of its flower.

*Sida corrugata* (47b). Only a flower.

*Sida virgata* (144b, 156b). Only a flower bush, no use.

*Sida inclusa* (96b). alputadi, Pintubi. Fruit eaten.

*Cienfuegosia gossipioides* (49b). Only a flower.

## STERCULIACEAE

*Rulingia loxophylla* (88b). No name, only a flower.

*Brachychiton gregorii* (51a). nalta, Pintubi. nalta, Ngalia. nalta, Aranda. 'naltatjita, Pintubi (the seeds). Eat the seeds milled, considered a very fattening food.

## DILLENIACEAE

*Hibbertia glaberrima* (46a). 'jukuri, Ngalia.

## MYRTACEAE

*Eucalyptus camaldulensis* (16a). Red Gum. 'napari, Ngalia. 'pira, 'pa'ra, Aranda.

*Eucalyptus terminalis* (103a). Bloodwood. arkanka, Aranda. Not used except as giving honey when in flower. This bloodwood grows six to eight feet tall on the slopes of rocky hills, and as larger trees on flat ground.

*Eucalyptus gamophylla* (128b). 'warilja, Pintubi. 'alba, Aranda. No use is made of it.

*Melaleuca glomerata* (11b). 'ilbili, Kukatja. 'ilbala, Aranda.

*Melaleuca linophylla* (42a). 'ilbili, Pintubi. 'ilbila, Aranda. Grows in the sandhill country by watercourses.

## UMBELLIFERAE

*Didiscus glaucifolius* (2a). Has no native name, emu food only.

## APOCYNACEAE

*Carissa brownii* (33a, 85a, 93a, 17b, 18b). 'namunboro, 'namunburo, Pintubi. 'manikitji, Ngalia. 'manikitja, Kukatja. 'inikitja, 'lalitja, e'nukitja, e'nokitja, Aranda. Grows at Ulambaura Spring. The purplish fruits are eaten; the taste is considered by aborigines to be very sweet, a good food.

## ASCLEPIADACEAE

*Sarcostemma australe* (15b). alk'naiknai, Aranda.

*Pentatropis kempeana* (88a, 18b). 'maua 'naraka, Aranda. "Good tucker; eat the leaves; when they find it while hunting, they always stop and eat their fill of it."

*Marsdenia australis* (21b). ondorono, Pintubi. 'ondorokno, Kukatja. al'tjeia, Aranda. Eat the fruit.

## CONVOLVULACEAE

*Ipomoea* sp. (in leaf only) (57b, 67b). Leaves and stem only used. No potato, only a flower. No name.

*Convolvulus erubescens* (152b). 'tnalja tnalja, Aranda. All cooked and eaten, steamed and stripped to get only the leaves. Long time ago lives on this. It is cooked in the same manner as *Lepidium*.

*Breweria rosea* (48b). Only a flower.

*Evolvulus alsinoides* (58b). Only a flower; no use.

#### BORRAGINACEAE

*Heliotropium asperum* (7b). Only a flower.

*Heliotropium undulatum* (100a). Has no native name, "only a flower".

*Trichodesma zeylanicum* (46b). Only a flower.

#### VERBENACEAE

*Dicrastylis gilesii* F. Muell. (110b). Taliperta Spring, Mt. Palmer Range. Only a flower.

*Spartothamnella teucriflora* (76b). alk'neiak'neia, Aranda. Food for birds and emus.

*Clerodendron floribundum* (30a, 61a). 'cremari, Ngalia. 'cremarta, Aranda. The purple fruit is eaten; also the carrot-like roots. Grows at Ulambaura Spring.

#### LABIATAE

*Prostanthera striatiflora* (131a). tjiruka tjiruka, 'tjurika 'tjurika, Aranda. Pound with stones; the plant is then put in a dish (wooden), water poured in and heated with hot stones; allowed to go cold and the body washed with it; a good medicine.

#### SOLANACEAE

*Solanum centrale* (77a, 90b). kararuba, kamburarupa, Pintubi. 'karalba, kararupa, Ngalia. 'katjara, Aranda. Agrees with a specimen from Liddle Hill, with a rusty tomentum like this, identified by J. M. Black as *S. centrale* which appears to be distinct from *S. nemophilum*. Leaves with a rusty tomentum. Fruit green then yellow, slightly elongated, 1.7 × 1.2 cm. Fruit like a plum, eaten.

*Solanum* sp. (10b). With occasional small prickles thickened downwards on the stems and even on calyx. Leaves with paler tomentum than *S. nemophilum* but perhaps a form of this species. Not 'wangi; only a flower.

*Solanum orbiculatum* (73a, 9b). 'itumba, Aranda. kamburarupa, Pintubi. Fruit green, spherical 8 mm. diam., becoming whitish and dry. Good fruit, eaten.

*Solanum coactiliferum* (100b, 166b). 'itumba, Pintubi. 'etunba, Aranda. It is a food. The 'mana, yellow spherical fruit, are eaten.

*Solanum ellipticum* (64a, 74a, 125a, 8b, 56b, 60b, 68b, 99b, 121b, 122b, 123b). 'kuilpura, wanji, Pintubi. wanji, wanji, Kukatja. wanji, Ngalia. Fruit eaten at all times and is an important staple diet of emu, kangaroo, dogs and people.

*Solanum ellipticum* var. (127a). a'leljaka, Aranda. The small green fruits are good food.

*Solanum quadriloculatum* (11a, 111a, 62b). 'warakalukalu, Pintubi. arcilba, 'erujalkna, Aranda. Only a kangaroo food; not the same species as wanji though very like it; fruit not eaten.

*Solanum quadriloculatum* ? (162b). 'wangi, Kukatja. alparandji, randa, Aranda. Fruit is called karjera and is thought to be a far smaller plant than 'wangi.

- Solanum eremophilum* (5b, 6b, 36b). 'wciageri, Pintubi. werinwerinba, Kukatja. a'ljeljaka, Aranda. Yields a fruit very nice to eat. Fruit 1 cm. diameter, green to pallid.
- Solanum* sp. aff. with *S. phlomoides* A. Cunn. and *S. melanospermum* F. Muell. (1b, 12b, 13b, 103b, 165b, 167b). Lobed leaves. Fruit large on long recurved pedicles, long spines on calyx which is ribbed. 'kura, 'pura, Pintubi. 'kura, 'pura, Kukatja. 'pigi, Aranda. Large fruit, the black seed in this fruit is thrown away, the skin and flesh only being eaten.
- Solanum melanospermum* F. Muell. (prob.) (37a, 51b, 59b). Both numbers 51b and 59b were given the same native name as *Solanum* sp. aff. *S. phlomoides*. No. 51b has deeply lobed leaves and delicate prickles on the stem, and occasionally on the leaves and even on the calyx. No fruit. No. 59b has rather short pale prickles on the stem and petioles but none on the leaves and calyx. The leaves seem undulate. There is a whitish dried fruit about 1 cm. in diameter in a rather short recurved pedicel. These two plants are considered to be probably *S. melanospermum* and the native identification incorrect. One would naturally infer that their identification was more likely to be correct than ours but it should be remembered that the natives were shown a broken-off branch and did not see the plant growing with its natural habit. 'kura, 'pura, Pintubi. 'kura, Kukatja. 'kura, Ngalia. 'pigi, Aranda. Large tomato-like fruit eaten. The black seed in it is taken out and thrown away and is spoken of as 'not good', only the flesh and skin being eaten. It is called 'good food'.
- Solanum petrophilum* (14b). Given the same native name as *Solanum* sp. aff. *S. phlomoides*. Very numerous white spines up to 1-3 cm. long on the stem, common on the leaves and on the calyx. Leaves shortly lobed. A dried white fruit is 9 mm. diameter. This is considered to be *S. petrophilum* and the native identification incorrect. 'kura, 'pura, Pintubi. 'kura, Kukatja. 'pigi, Aranda. Has a good fruit like a tomato which is eaten. [The fruit of *S. petrophilum* is hard and not edible.]
- Datura leichardtii* (139b). a'ranga'rakata, Aranda. No use is made of it. Once two boys ate these and they became drunk. Their mother wanted to know what was wrong. Very "strong" and dangerous, only makes one drunk.
- Nicotiana rotundifolia* Lindl. (38a). mingulba, Pintubi. 'mingul'mingulba, Aranda. Not used by Aranda.
- (70). 'ingul'ingulba, Aranda. Chew it when nothing better is available.
- Nicotiana gossei* Domin. (56a). pitjuri, Aranda. ingulba, Aranda.
- Nicotiana* sp. ? nov. aff. *N. gossei*. Dr. H. Eichler, State Botanist, reports: "This species is characterized by the long flowers similar to *N. gossei* and *N. rotundifolia*, the pubescence of *N. gossei* and *N. rotundifolia*, the short calyx (ca. 9-11 mm.), the cauline leaves having not such a broad base as is characteristic for *N. gossei*, and the inflorescence being more elongated than in *N. gossei* and resembling more *N. ingulba*."
- (3a). mingulmingulba, Kukatja. ingulingulba, Aranda. Not used for any purpose by the Aranda. This species grows near water. The species on the sandhills and the one on the ranges are chewed by all.
- (32a). tjunbumbu, Ngalia. pitjuri, Aranda. This species is the hills tobacco and is considered a good kind.
- (136a). ingulba, Pintubi. pitjuri, Aranda.
- (111b). mingulba, Pintubi. ingulba, Aranda. This *Nicotiana* is chewed with ashes.

(141b). *ingulingulba*, Aranda. Some people use it as a tobacco. (The differences in native nomenclature and use are perhaps due to their mis-identifying the insufficient material.)

*Nicotiana velutina* (136b). *mingulmingulba*, Pintubi. *ingulingulba*, Aranda. Sometimes men chew it when they have no pitjuri. It is wilted in hot ashes but is not as good as *ingulba*.

(*Nicotiana ingulba* with its very long corolla tube was also collected and is used by the natives. However, a specimen was not submitted for the native name.)

#### SCROPHULARIACEAE

*Stemodia viscosa* (104a). Has no native name. Has a strong smell; to make a medicine, it is put in boiling water and allowed to cool; in use the head is washed with the liquid. It is considered a good medicine.

#### BIGNONIACEAE

*Tecoma doratoxylon* (44a). 'urtjanba, Pintubi. 'winbiri, Kukatja. 'wianbiri, Ngalia. 'janbara, Aranda. The wood of this shrub, because of its flexibility and strength, is considered to be the best spear wood. Short lengths are spliced together when long ones are not available.

#### MYOPORACEAE

*Myoporum montanum* (147b). *tjuruku tjuruku*, Aranda. Used as medicine, steep in water with hot stones in dish, wash head with it; very strong medicine. "Heat branches in fire and spread down, lie on them for medicine."

*Eremophila latrobei* (32b). *knjilana*, Aranda. Eat the bases of the flowers, pull off flower and eat base; is very sweet sugar = *ŋkwald*.

*Eremophila gilesii* (24a, 79b). 'molili, Pintubi. 'knji-lanja, Aranda. Emu food, also a native medicine; boil it, wash the body with the liquid for the cure of body sores.

*Eremophila sturtii* (109a). "Kerosene Bush." 'ŋkottŋkota, Aranda. Has no use.

*Eremophila longifolia* (20a). 'ŋalurupa, Pintubi, Kukatja. *tnuruja*, Aranda. Has no use.

*Eremophila freelingii* (124b). 'aratja, Pintubi. 'aratja, Aranda. Euros eat it.

*Eremophila goodwinii* (50b). Only a flower, no food. Unpleasant smell.

#### RUBIACEAE

*Plectronia latifolia* (86a). *awulura*, Pintubi. *agia*, Aranda. This wild currant is plentiful on the sandhills and on the ranges.

#### CUCURBITACEAE

*Melothria maderaspatana* (133a, 39b). 'elkart'elk(w)arta, Aranda. Kangaroos eat the fruits; has no other use.

*Citrullus vulgaris* (60a). *kura*, Kukatja. *pikia*, Aranda. The introduced pie melon, blackfellow melon.

#### CAMPANULACEAE

*Isotoma petraea* (157b). "Euro fingers" is one of names. 'mara'kanjala, Pintubi. 'iraneratja, Aranda. 'Very strong.' If eat this with pitjuri it makes one very drunk, very strong.

#### GOODENIACEAE

*Goodenia larapinta* Tate (25a). Has no native name.



## COMPOSITAE

- Brachycome ciliaris* (67a). Has no native name, "only a flower".
- Calotis latiuscula* (109b). tjintatjinta, Pintubi, Kukatja, Aranda. Kangaroo and emu food only.
- Calotis hispidula* (66a, 132b). tjilga, Pintubi. tongara, Aranda. Nuisance only (from the spines); hard to find place to camp where there are none.
- Siegesbeckia orientalis* (12a). Has no native name. Only a flower; no use except that it is used to decorate the hair of girls.
- Podocoma cuneifolia* (142b). Only a flower.
- Olearia subspicata* (98b). Only a flower, no name.
- Glossogyne tenuifolia* (117b). 'enomarta, enmorta, Aranda. Emu food.
- Senecio magnificus* (137b). 'knulja, knamba, Ielena, 'knuljaknambalelena, Aranda. Only a flower.
- Senecio gregorii* (122a). Has no native name and no use, only a flower.
- Helipterum floribundum* (72a). Has no native name, only a flower.
- Helipterum stipitatum* (41a, 112b). eno:tji (a flower), Pintubi. 'wamala-'wamula, Ngalia. andata, Aranda. (The Aranda speak of it only under this general name, meaning a flower.) andata mara, a good or pretty flower.
- Helipterum thomsoni* (153b). Only a flower.
- Helichrysum apiculatum* (3b). 'kembakemba, Aranda. "Only a flower."
- Helichrysum bracteatum* (26a). Has no native name, "only a flower".
- Helichrysum ambiguum* (9a). Has no native name and no use.
- Rutidosis helichrysoides* (4a, 114b). kembakemba, Pintubi. kembakemba, Aranda. Not used.
- Myriocephalus stuartii* (29a, 108a). Has no native name, "only a flower".
- Calocephalus multiflorus* (10a, 113b). Has no native name and is not used; only a flower.
- Sonchus oleraceus* (79a). The introduced Sow Thistle. 'ulbu'rulbura. "Came with the white man; not eaten."

## FUNGI

- Pisolithus (Polysuccum) tinctorius*. awingura, Aranda. Said by the aborigines to grow under mulga trees.
- Phellorhina* sp. No native name or use.

# **REVISION OF THE TATE MOLLUSCAN TYPES - SCAPHOPODA.**

*BY N. H. LUDBROOK*

## **Summary**

The present paper is the first of a series revising the molluscan species described by Tate. The scaphopoda are all lodged in the Tate Museum Collection, University of Adelaide.

## REVISION OF THE TATE MOLLUSCAN TYPES — SCAPHOPODA.

by N. H. LAMBROOK\*

[Read 11 September 1958]

### SUMMARY

The present paper is the first of a series revising the molluscan species described by Tate. The scaphopoda are all lodged in the Tate Museum Collection, University of Adelaide.

### INTRODUCTION

At the suggestion of Dr. M. F. Glaessner the writer has undertaken, on a long-term basis, the revision of the type collection of mollusca described by Ralph Tate between 1878 and 1899.

For the 50 years following the death of Tate in 1901 this material constituted the principal basis of Tertiary correlation in South Australia. It is now desirable that the mollusca be revised and aligned with the microfaunas which have been studied during the last six years at the University of Adelaide and the South Australian Department of Mines.

The scaphopod species are all in the Tate Museum Collection. They are a small group of some significance in stratigraphic interpretation.

Phylum MOLLUSCA

Class SCAPHOPODA

Family DENTALIIDAE

Genus DENTALIUM Linné, 1758

Type species (s.d. Montfort, 1810) *Dentalium elephantinum* Linné

Subgenus DENTALIUM s. str.

*Dentalium* (*Dentalium*) *aratum* Tate

pl. 1, fig. 3

*Dentalium aratum* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, p. 192, pl. 20, fig. 8.

*Dentalium aratum* Tate, Harris, 1897, Cat. Tert. Moll. Brit. Mus., 1, p. 293.

*Dentalium aratum* Tate, Pilsbry & Sharp, 1898, Tryon's Man. Conch., 17, p. 199.

*Dentalium* (*Episiphon*) *aratum* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 265.

*Dentalium aratum* Tate, Chapman & Crespin, 1928, Rec. Geol. Surv. Vic., 5 (1), p. 159.

*Dentalium* (*Paradentalium*) *aratum* Tate, Cotton and Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 223.

**Diagnosis**—A small *Dentalium* with from 6 to 8 primary ribs narrower than the interspaces with fine secondary riblets and threads developing anteriorly. Strongly curved posteriorly, nearly straight anteriorly.

**Description of Holotype**—Shell small, fairly strongly arcuate, polygonal in section with 7 strong primary ribs and fine longitudinal threads or riblets in the interspaces. Ribs narrow, interspaces wide, shell strongly curved posteriorly, straightening anteriorly, gradually tapering. Apex and aperture polygonal.

**Dimensions**—Length 20 mm., diameter at apex 1 mm., diameter at aperture 2 mm., arc 2 mm.

\* Department of Mines, Adelaide. Published with the permission of the Director of Mines.

*Type Locality*—Cadell Marl Lens, River Murray, 4 miles below Morgan, Hundred Cadell, Section G; Lower Miocene.

*Holotype*—Tate Mus. Coll., T 256A.

*Material*—On original tablet T 256 holotype and 25 paratypes in 3 rows: top row numbered 1—1 seven paratypes Muddy Creek, numbered 4 one paratype Spring Creek; middle row numbered 5—5 four paratypes Gellibrand, the holotype, and 4 paratypes R. Murray; bottom row numbered 2 one paratype Fyansford, numbered 3 two paratypes Schnapper Point, 6 paratypes R. Murray.

The original description cites the species as occurring in the Mulloowurtie Clays, but no specimens from this locality are in Tate's material.

*Stratigraphical Range*—Miocene-?Pliocene.

### **Dentalium (Dentalium) latesulcatum Tate**

pl. 1, fig. 1

*Dentalium latesulcatum* (err. pro *latesulcatum*) Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 262, pl. 8, fig. 9.

*Dentalium (Paradentalium) howchini*, Cotton & Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 224, pl. 12, fig. 6.

*Dentalium (Dentalium) latesulcatum* Tate, Ludbrook, 1936, Trans. Roy. Soc. S. Aust., 79, pp. 1-2, pl. 1, figs. 10-14 (gives full synonymy).

*Diagnosis*—A short thick solid *Dentalium* with 7 to 16 strong primary ribs approximately equal to interspaces in which secondary ribs may be developed by intercalation.

*Description of Holotype*—Shell short, thick, solid, only very slightly curved, rapidly tapering, sculptured with 10 strong primary ribs narrower than the interspaces in which secondary riblets rise near the aperture by intercalation. Interspaces irregularly and strongly crossed by growth striae which pass less conspicuously over the ribs. Apex with a notch. Aperture circular internally, polygonal externally.

*Dimensions*—Length 40 mm., diameter at apex 3 mm., diameter at aperture 8 mm.

*Type Locality*—Grange Burn, Hamilton, Victoria; Grange Burn Coquina, Pliocene.

*Holotype*—Tate Mus. Coll., T 1610A.

*Material*—The holotype and 6 paratypes on original tablet; specimens labelled *Dentalium elephantinum* and recorded as such (Tate, 1890, p. 177) Dry Creek Bore.

*Stratigraphical Range*—Pliocene.

### **Subgenus ANTALIS H. Adams & A. Adams, 1854**

Type species (s.d. Pilsbry & Sharp, 1897) *Dentalium entalis* Linné

### **Dentalium (Antalis) bifrons Tate**

pl. 2, fig. 2

*Dentalium (?) bifrons* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, pp. 192-3, pl. 20, fig. 5.

*Dentalium bifrons* Tate, Tate & Derrant, 1893, Trans. Roy. Soc. S. Aust., 17 (1), p. 223.

*Dentalium bifrons* Tate, Harris, 1897, Cat. Fert. Moll. Brit. Mus., 1, p. 285.

*Dentalium bifrons* Tate, Pilsbry & Sharp, 1898, Tryon's Man. Conch., 17, p. 200.

*Dentalium (Fissidentalium) bifrons* Tate, Cotton & Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 222.

*Diagnosis*—A large solid, gradually tapering and only slightly curved *Antalis*, finely ribbed in the posterior one-quarter, obsolete or smooth elsewhere but for conspicuous oblique growth lines. Apex with or without slit.

*Description of Holotype*—Shell large and solid, only slightly curved, more so in the posterior one-third, nearly straight in the anterior two-thirds. Posterior one-quarter with about 40 fine ribs which rapidly become obsolete. Anterior portion of shell smooth, with microscopic and conspicuous oblique growth striae. Shell gradually tapering over all. Apex circular in the holotype, without slit. Aperture circular, only slightly oblique.

*Dimensions*—Length 92 mm., diameter at apex 2 mm., diameter at aperture 9.4 mm., arc 3.6 mm.

*Type Locality*—Muddy Creek, Hamilton, Victoria; Grange Burn Coquina, Pliocene.

*Holotype*—Tate Mus. Coll., T 255.

*Material*—On tablet T 255, the holotype and 2 paratypes from Muddy Creek, one paratype Spring Creek. One large topotype 96 mm. long with apical slit 5.5 mm.

*Stratigraphical Range*—Miocene-Pliocene.

### **Dentalium (Antalis) sectiforme Tate**

pl. 2, fig. 5

*Dentalium (Graptacme) sectiforme* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 262, pl. 8, figs. 6, 6a.

*Dentalium (Graptacme) sectiforme* Tate, Cotton and Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 225.

*Diagnosis*—A small, slender *Antalis*, moderately curved, sculptured posteriorly with fine riblets increasing by intercalation from about 16 at the apex to about 30 where they become obsolete in the anterior quarter.

*Description of Holotype*—Shell small, very slender and gradually tapering, fairly thin but solid, glossy, translucent, sculptured in the posterior three-quarters with fine riblets, 16 at the apex increasing by intercalation to about 30 at the anterior one-quarter where they become obsolete, but are still visible under the microscope. Anterior quarter showing fine growth striae.

Aperture circular, peristome thin; apex with a short slit and small supplementary pipe.

*Dimensions*—Length 11 mm., diameter at apex 0.05 mm., diameter at aperture 2.2 mm., arc 1.5 mm.

*Type Locality*—Muddy Creek, Victoria; Grange Burn Coquina, Pliocene.

*Holotype*—Tate Mus. Coll., T 1615A.

*Material*—The holotype and 5 paratypes.

*Stratigraphical Range*—Lower Pliocene of Muddy Creek.

Subgenus *FUSTIARIA* Stoliczka, 1868

Type species (s.d. Pilsbry & Sharp, 1897) *D. circinatum* Sowerby

### **Dentalium (Fustiaria) tornatissimum Tate**

pl. 2, figs. 6, 7

*Dentalium (Episiphon) tornatissimum* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 265, pl. 8, figs. 7-7a.

*Dentalium (Episiphon) tornatissimum* Tate, Cotton and Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 226-7.

*Diagnosis*—A very small solid *Fustiaria* with conspicuous annular grooves, about 8 per mm.

*Description of Holotype*—Shell small but solid, nearly straight, sculptured with incised annular grooves, varying from 10 per mm. in the apical portion to less than 8 towards the aperture. Apex with a short terminal pipe, aperture broken, circular in section.

*Dimensions*—Length 7.3 mm., diameter at aperture 1.37 mm., diameter at apex 0.55 mm., arc 0.27 mm.

*Type Locality*—Jemmy's Point, Gippsland; Jemmy's Point Formation, Kalimnan (Pliocene).

*Holotype*—Tate Mus. Coll., T 1609.

*Material*—The holotype and paratype.

*Stratigraphical Range*—Kalimnan (Pliocene).

Subgenus *GADILINA* Foresti, 1895

Type species (monotypy) *D. triquetrum* Brocchi, 1814

*Dentalium (Gadilina) tatei* Sharp & Pilsbry

pl. 1, fig. 5

*Dentalium* (?) *triquetrum* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, p. 193, pl. 20, fig. 3 (*non* Brocchi, 1814).

*Dentalium tatei* Sharp & Pilsbry, 1898, Tryon's Man. Conch., 17, p. 218 (*nom. nov.*).

*Dentalium (Gadilina) tatei* Sharp & Pilsbry, Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 266.

*Dentalium (Gadilina) tatei* Pilsbry & Sharp, Cotton & Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 227.

*Diagnosis*—A small but solid *Gadilina*, very slightly curved.

*Description of Holotype*—Shell small, solid, smooth but for microscopic growth lines, thick, only very slightly curved and only slightly tapering. Laterally compressed. Aperture broken, apex triangular in section.

*Dimensions*—Length 10 mm., diameter at apex 0.7 mm.

*Type Locality*—Adelaide Bore, Kent Town, glauconitic sands, Upper Eocene.

*Holotype*—Tate Mus. Coll., T 252A.

*Material*—The holotype and six paratypes.

*Stratigraphical Range*—Upper Eocene.

Subgenus *LAEVIDENTALIUM* Cossmann, 1888

Type species (o.d.) *D. incertum* Deshayes

*Dentalium (Laevidentalium) acriculum* (Tate)

pl. 1, fig. 2

*Entalis acriculum* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, p. 192, pl. 20, fig. 11.

*Dentalium lacteum* Tate, 1887, *ibid.*, p. 193, *non* Deshayes.

*Dentalium acriculum* Tate, Pilsbry & Sharp, 1898, Man. Conch., 17, p. 197.

*Dentalium (Laevidentalium) lacteolum* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 264.

*Dentalium (Fustiaria) acriculum* Tate, 1899, *ibid.*

*Dentalium (Laevidentalium) lacteolum* Tate, Cotton and Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 226.

*Dentalium (Fustiaria) acriculum* (Tate), Cotton and Ludbrook, 1938, *ibid.*

*Diagnosis*—A small, smooth, thin, gently curved *Laevidentalium*.

*Description of Holotype*—Shell small, thin, subulate, gently curved, smooth, polished, with microscopic growth lines. Apex with a slit, aperture circular, oblique.

*Dimensions*—Length 33 mm., diameter at apex 0.85 mm., diameter at aperture 2.5 mm., arc 2.0 mm.

*Type Locality*—Muddy Creek, Victoria; Muddy Creek Marls, Lower Miocene.

*Holotype*—Tate Mus. Coll., T 251.

*Material*—On tablet T 251 the holotype and 8 paratypes (Muddy Creek); on tablet T 253 originally labelled *Dentalium lacteum* Deshayes and later corrected to *Dentalium lacteolum* Tate, six specimens Muddy Creek, one Gelli-

brand. Tate separated these from *acriculum* on the absence of the apical fissure which is not regarded as a diagnostic feature. 3 of the paratypes of *acriculum* have no fissure and the two species are indistinguishable.

The annular striae of the type description are merely very faint growth striae.

*Stratigraphical Range*—Lower Miocene.

***Dentalium (Laevidentalium) australe* Sharp & Pilsbry**

pl. 2, fig. 1

*Eulalis annulatum* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, pp. 191-2, pl. 20, figs. 6a, 6b, non Gmelin, nec Meyer, nec Sandbergér.

*Dentalium australe* Sharp & Pilsbry, 1898, Tryon's Man. Conch., 17, p. 199 (nom. mut.).

*Dentalium (Fustaria) australe* Sharp & Pilsbry, Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), pp. 264-5.

*Dentalium (Fustaria) australe* Sharp & Pilsbry, Cotton and Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 226.

*Diagnosis*—A fairly large solid *Laevidentalium* nearly straight in the adult, with conspicuous fairly even growth striae, about 6 per mm.

*Description of Holotype*—Shell stout, fairly large and evenly tapering, only slightly curved, more particularly in the posterior one-third. Shell smooth but for conspicuous incised and fairly even growth striae, generally about 6 per millimetre. Apex rounded with a slit about 3 mm. long. Aperture circular, not oblique.

*Dimensions*—Length 68 mm., diameter of apex 2 mm., diameter of aperture 7 mm., arc 2 mm.

*Type Locality*—Muddy Creek, Victoria; Muddy Creek Marls, Lower Miocene.

*Holotype*—Tate Mus. Col., T 250A.

*Material*—The holotype and 3 paratypes, on tablet with six mounted specimens. The holotype is the second from the left, the paratype third from the left is a specimen 53 mm. long of which the apex with terminal pipe was figured (Tate, 1887, pl. 20, fig. 6b).

Two specimens, the extreme left and the second from right on the tablet, do not belong to the species but to a large undescribed species on tablet T 258 with 4 specimens of *D. subfissura* from the Murray Cliffs.

The dimensions of the holotype are incorrectly given in the original description.

*Stratigraphical Range*—Upper Oligocene-Lower Miocene.

***Dentalium (Laevidentalium) largicrescens* Tate**

pl. 1, fig. 4

*Dentalium largicrescens* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 264, pl. 3, figs. 10, 10a.

*Dentalium largicrescens* Tate, Chapman & Cressin, 1928, Rec. Geol. Surv. Vic., 5 (1), p. 159.

*Dentalium (Laevidentalium) largicrescens* Tate, Cotton and Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 225.

*Diagnosis*—A short, solid, rapidly tapering and slightly curved *Laevidentalium*.

*Description of Holotype*—Shell of moderate size, moderately thick, smooth and shining with conspicuous slightly oblique growth striae. Shell rapidly tapering, gently curved in the posterior one-third but only slightly curved towards the aperture. Apex circular, thick, with an apical fissure on the ventral side, aperture circular, relatively thin.



*Dimensions*—Length 44 mm., diameter at apex 1.0 mm., diameter at aperture 6.5 mm., arc 2.5 mm.

*Type Locality*—Beaumaris, Victoria; Sandringham Sands, Black Rock Member, Cheltenhamian (Upper Miocene).

*Holotype*—Tate Mus. Coll., T 1611.

*Material*—On tablet T 1611, the holotype and five paratypes from Beaumaris, one paratype from the Pliocene of Muddy Creek. One specimen Muddy Creek.

*Stratigraphical Range*—Cheltenhamian (Upper Miocene)—Kalmian (Lower Pliocene).

### *Dentalium (Laevidentalium) pictile* Tate

pl. 2, fig. 4

*Entalis subfissura* Tate, Tate and Dennant, 1896, Trans. Roy. Soc. S. Aust., 20 (1), p. 134.

*Dentalium (Laevidentalium) pictile* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 263, pl. 8, fig. 8.

*Dentalium (Laevidentalium) pictile* Tate, Cotton and Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 225.

*Diagnosis*—A strongly curved *Laevidentalium* of moderate size, evenly tapering.

*Description of Holotype*—Shell slender, of moderate size, gradually tapering, strongly curved, smooth but for fine growth striae, dark grey to black in colour with light bands. Apex slightly oval, with a short broad notch, aperture rounded, oblique.

*Dimensions*—Length 52 mm., diameter at apex 1 mm., diameter at aperture 5 mm., arc 6.5 mm.

*Type Locality*—Table Cape, Tasmania; Oligocene.

*Holotype*—Tate Mus. Coll., T 1608.

*Material*—Tablet T 1608 with holotype and paratype only.

*Stratigraphical Range*—Upper Oligocene—Lower Miocene.

### *Dentalium (Laevidentalium) subfissura* (Tate)

pl. 2, fig. 3

*Entalis subfissura* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, p. 191, pl. 20, figs. 4a-b.

*Dentalium subfissura* Tate, Harris, 1897, Cat. Tert. Moll. Brit. Mus., (1), p. 296; Pilsbry & Sharp, 1898, Man. Conch., 17, p. 216.

*Dentalium subfissura* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 263.

*Dentalium subfissura* Tate, Chapman & Cressin, 1928, Rec. Geol. Surv. Vic., 5 (1), p. 159.

*Dentalium (Laevidentalium) subfissura* Tate, Cotton & Ludbrook, 1938, Trans. Roy. Soc. S. Aust., 62 (2), p. 225.

*Diagnosis*—An evenly tapering and moderately arcuate *Laevidentalium* of moderate size.

*Description of Holotype*—Shell of moderate size for the subgenus, thin, subulate, slightly compressed dorso-ventrally, smooth except for oblique growth striae. Apex small, subcircular, with a fairly broad V-shaped notch on the ventral side and a small supplementary pipe. Aperture oblique, slightly oval, dorso-ventrally compressed.

*Dimensions*—Length 46 mm., diameters at aperture 4 and 4.25 mm., diameter at apex 1 mm., arc 4 mm.

*Type Locality*—River Murray Cliffs 4 miles downstream from Morgan, Hundred of Cadell, Section G. Morgan Limestone (Lower Miocene).

*Holotype*—Tate Mus. Coll., T 249A.

*Material*—On tablet the holotype and the following paratypes: River Murray 2, Muddy Creek 3, Gellibrand River 3, Spring Creek 1, Schnapper Point 2, Aldinga Bay (Blanche Point Marls) 3, Corio Bay 1. Table Cape specimen was

evidently removed from the tablet and described as *D. pictile*, the holotype of which just fits the unfaded space. T 258 consists of 4 topotypes from River Murray, and one large *Laevidentalium* belonging to another species.

Also in the Tate Collection 1 specimen Dry Creek Bore, 34 examples unlocalized probably from Muddy Creek, 1 specimen from the Eocene of Adelaide Bore, 12 specimens Schnapper Point, 12 specimens Blanche Point Marls, 11 topotypes River Murray, 27 specimens Muddy Creek.

*Stratigraphical Range*—Upper Eocene to Lower Miocene. Common in Lower Miocene of Murray Basin.

Family SIPHONODONTALIIDAE Simroth, 1894

Genus CADULUS Philippi, 1844

Type species (monotypy) *Dentalium ovulum* Philippi

Subgenus GADILA Gray, 1847

Type species (o.d.) *Dentalium gadus* Montagu

*Cadulus (Gadila) mucronatus* Tate

pl. 1, fig. 8

*Cadulus mucronatus* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, p. 193, pl. 20, fig. 10.

*Cadulus mucronatus* Tate, Harris, 1897, Cat. Tert. Moll. Brit. Mus., 1, p. 297.

*Cadulus mucronatus* Tate, Pilsbry & Sharp, 1898, Tryon's Man. Conch., 17, p. 237.

*Cadulus mucronatus* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 266.

*Diagnosis*—A small *Gadila*, bulging slightly to the anterior of the middle. Gently curved, fairly rapidly tapering at each end. Wider anteriorly than towards the apex.

*Description of Holotype*—Shell fairly small, solid, narrow, gently arcuate on the ventral surface and bulging on the dorsal surface. Contraction towards the anterior aperture fairly pronounced over 2 mm.; contraction to the posterior more gradual over a length of 3 mm.

Aperture broken in the holotype, otherwise oblique, apex also broken, otherwise rounded, sharp, and thickened within.

Surface smooth, polished, with slightly oblique growth lines and faint signs of banding to the anterior.

*Dimensions*—Length 6.3 mm., diameter at apex 0.7 mm., at aperture 1.0 mm., at swelling 1.63 mm.

*Type Locality* (here designated)—Muddy Creek, Victoria; Muddy Creek Marls, Lower Miocene.

*Holotype*—Tate Mus. Coll., T 229A.

*Material*—The holotype and 14 paratypes in 2 rows mounted on card in box mounted on tablet labelled "*Cadulus mucronatus* Tate pl. XX., fig. 10. Eocene Muddy Ck., 1 Spring Ck."

The holotype is the specimen at the left of the bottom row.

There is nothing on the card to indicate which specimens come from Muddy Creek and which from Spring Creek.

One large shell fifth from the left of the bottom row does not belong to the species.

*Stratigraphical Range*—Lower Miocene.

*Cadulus (Gadila) acuminatus* Tate

pl. 1, fig. 7

*Cadulus acuminatus* Tate, 1887, Trans. Roy. Soc. S. Aust., 9, p. 194.

*Cadulus (Gadila) acuminatus* Tate, Pilsbry & Sharp, 1898, Tryon's Man. Conch., 17, p. 183.

*Cadulus (Gadila) acuminatus* Tate, 1899, *id.* 23 (2), p. 266, pl. 8, fig. 12.

*Cadulus acuminatus* Desh. Dennant & Kitson, 1903, Rec. Geol. Surv. Vic., 1 (2), p. 143.

*Cadulus acuminatus* Tate, Ludbrook, 1941, Trans. Roy. Soc. S. Aust., 65 (1), p. 101.

*Cadulus* (*Gadila*) *acuminatus* Tate, Ludbrook, 1956, *id.* 79, p. 5, pl. 1, fig. 2.

*Diagnosis*—A very small *Gadila* slightly curved and not bulging.

*Description of Holotype*—Shell rather thin, very small, slightly curved, gently tapering anteriorly and slightly more so posteriorly. Dorsal face with gentle curvature, ventral face somewhat more arcuate. Surface of shell somewhat eroded, otherwise smooth.

Apex circular, slightly oblique, thin; aperture small, circular, thin.

*Dimensions*—Length 5.3 mm., diameter at the middle 1 mm., diameter at aperture 0.75 mm.

*Type Locality*—Aldinga Bay, Oyster Beds, Pliocene.

*Holotype*—Tate Mus. Coll., T 231A.

*Material*—The holotype (the middle specimen) and 2 paratypes mounted on card in tube on tablet labelled "*Cadulus acuminatus* Deshayes Miocene Aldinga".

Tate's (1899, p. 266) explanation of his use of Deshayes's MSS name is sufficiently clear. Deshayes's material has not yet been described; the tablet as originally labelled is still in the British Museum.

*Stratigraphical Range*—Pliocene of Aldinga Bay and the Adelaide Basin.

### *Cadulus* (*Gadila*) *infans* Tate

pl. 1, fig. 6

*Cadulus infans* Tate, 1899, Trans. Roy. Soc. S. Aust., 23 (2), p. 266, pl. 8, fig. 11.

*Diagnosis*—A very small *Gadila*, very slightly curved and slightly bulging in the anterior one-third.

*Description of Holotype*—Shell thin, white, smooth, very small, shining, slightly bulging in the anterior one-third and very gently tapering posteriorly, slightly more so in the anterior third. Dorsal face nearly straight, ventral face gently arcuate. Apex broken, apparently circular, aperture oblique, thin.

*Dimensions*—Length 3.2 mm., maximum diameter 0.51 mm., diameter at aperture 0.5 mm., arc 0.05 mm.

*Type Locality*—Muddy Creek, Victoria; Grange Burn Coquina, Pliocene.

*Holotype*—Tate Mus. Coll., T 1614.

*Material*—The holotype only.

*Stratigraphical Range*—Pliocene.

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TATE MOLLUSCAN TYPES  
EXPLANATION OF PLATES

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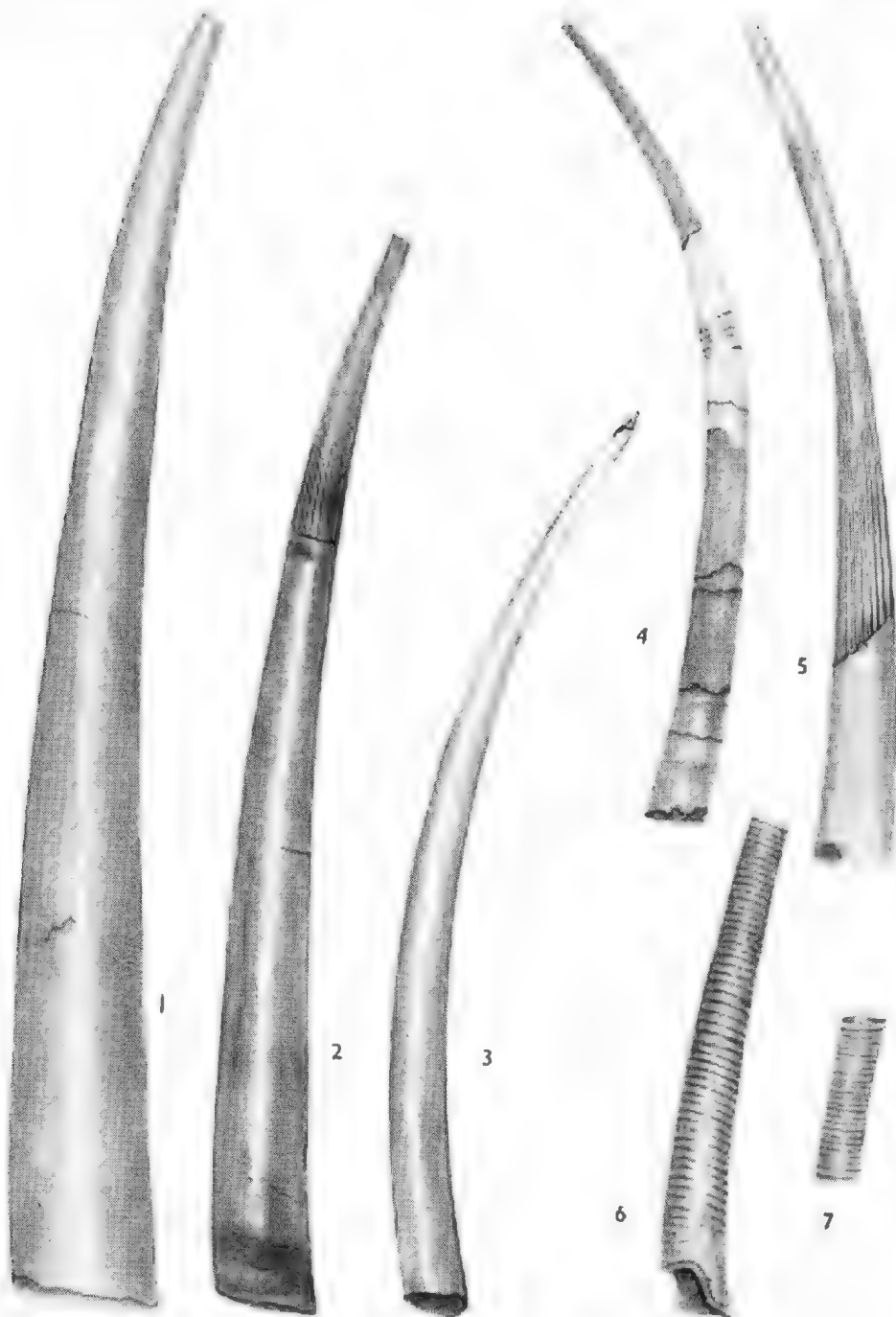
PLATE 1

- Fig. 1.—*Dentalium* (*Dentalium*) *lutesulcatum* Tate. Holotype, T 1610A, x 2.5.  
Fig. 2.—*Dentalium* (*Laevidentalium*) *acriculum* (Tate). Holotype, T 251, x 2.5.  
Fig. 3.—*Dentalium* (*Dentalium*) *aratum* Tate. Holotype, T 256A, x 5.  
Fig. 4.—*Dentalium* (*Laevidentalium*) *largicrescens* Tate. Holotype, T 1611, x 2.  
Fig. 5.—*Dentalium* (*Cadilina*) *tatei* Sharp & Pilsbry. Holotype, T 252A, x 12.  
Fig. 6.—*Cadulus* (*Gadila*) *infans* Tate. Holotype, T 1614, x 20.  
Fig. 7.—*Cadulus* (*Gadila*) *acuminatus* Tate. Holotype, T 231A, x 10.  
Fig. 8.—*Cadulus* (*Gadila*) *mucronatus* Tate. Holotype, T 229A, x 11.

PLATE 2

- Fig. 1.—*Dentalium* (*Laevidentalium*) *australe* Sharp & Pilsbry. Holotype, T 250A, x 2.5.  
Fig. 2.—*Dentalium* (*Antalis*) *bifrons* Tate. Holotype, T 255, x 1.5.  
Fig. 3.—*Dentalium* (*Laevidentalium*) *subfissura* (Tate). Holotype, T 249A, x 2.5.  
Fig. 4.—*Dentalium* (*Laevidentalium*) *pictile* (Tate). Holotype, T 1608, x 2.  
Fig. 5.—*Dentalium* (*Antalis*) *sectiforme* Tate. Holotype, T 1615A, x 10.  
Fig. 6.—*Dentalium* (*Fustiaria*) *tornatissimum* Tate. Holotype, T 1609A, x 9.  
Fig. 7.—*Dentalium* (*Fustiaria*) *tornatissimum* Tate. Paratype, T 1609B, x 9.





# SOME NEMATODE PARASITES FROM AUSTRALIAN HOSTS.

BY PATRICA M. THOMAS

## Summary

Four species are described as new, and amplified descriptions are given of six other species. The following are included: *Capillaria miniopterae* n. sp. (*Miniopterus blepotis*); *Amidostomum biziurae* Johnston & Mawson (*Biziuralobata*); *Nicollina echidnae* Baylis and *N. cameroni* n. sp. (*Tachyglossusaculeata*); *Nycteridostrongylus uncicollis* Baylis and *Molinostrongylus dollfus* n. sp. (*Miniopterus blepotis*); *Austrostrongylus thylogale* Johnston & Mawson (*Setonix brachyura*) ; *Pharyngodon australis* Johnston & Mawson ( *Tiliquascincoides* ) ; *Porrocaecum* (*Laymanicaecum* ) sp., immature ( *Emusium balloti* ) ; *Amplicaecum mackerrasae* nom. nov. syn. *Ophidascaris varani* Johnston & Mawson ( *Varanus varius* ) ; *Ophidascaris* sp. ( *Amphibolurus barbatus* ) ; *Hedruris longispicula* n. sp. (*Lygosoma challenger*); *Abbreviata bancrofti* (Irwin-Smith) (*Aspidites melanocephalus* ).



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by PATRICIA M. THOMAS\*

[Read 11 September 1958]

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### LIST OF PARASITES ARRANGED UNDER THEIR HOSTS

- Amusium balloti* Bernardi. Shark Bay, W.A. *Porrocaecum* (*Laymanicaecum*) sp.  
*Hemiscyllium ocellatum* Bonmatte. Low Is., Qu. *Proleptus australis* Baylis.  
*Lygosoma challengerii* Boulenger. Springbank, Qu. *Hedreris longispicula* n. sp.  
*Varanus varius* Shaw. Mt. Nebo, Qu. *Amplicaecum mackerrasae* nom. nov.  
*Aspidites melanocephalus* Krefft. Cairns, Qu. *Abbreviata bancrofti* (Irwin-Smith).  
*Amphibolurus barbatus* Cuvier. West Burleigh. *Polydelphis* sp.  
*Tiliqua scincoides* Shaw. Brisbane, Qu. *Pharyngodon australis* Johnston and Mawson.  
*Biziura lobata* Shaw. Purnong, S.A. *Amidostomum biziurae* Johnston and Mawson.  
*Tachyglossus aculeata* (Shaw and Nodder). Kangaroo Island, S.A.: *Nicollina echidnae* Baylis; *N. cameroni* n. sp.; Glen Davis, N.S.W.: *Nicollina echidnae* Baylis.  
*Setonix brachyura* Quoy and Gaimard. Rottnest Island, W.A. *Austrostrongylus thylogale* Johnston and Mawson.  
*Miniopterus blepotis* Temminck. Naracoorte, S.A.: *Nycteridostromgylus uncicollis* Baylis, *Molinosstrongylus dollfusi* n. sp. Canungra, Qu.: *Capillaria miniopterae* n. sp., *Nycteridostromgylus uncicollis* Baylis, *Molinosstrongylus dollfusi* n. sp.

### *Capillaria miniopterae* n. sp. (Figs. 1-3)

Four female and four male worms were taken from the stomach of *Miniopterus blepotis* from Canungra, Queensland.

The males are 8.0-8.3 mm. long, the females 11.1-14.4 mm. The body diameters are, in the male and female respectively, at the head 6 $\mu$ , 8.3 $\mu$ ; at

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the base of the oesophagus  $41-47\mu$ ,  $61\mu$ ; at the widest part of the body  $35.5\mu$ ,  $88-100\mu$ . The ratio of oesophageal to intestinal regions is as  $1:1.9-2.1$  in the female and  $1:1.6$  in the male.

The eggs are about  $50\mu$  by  $25\mu$ . The vulva lies close behind the end of the oesophagus and its position is marked by a large tubular flap of the cuticle. The anus in the female is  $20\mu$  from the rounded posterior end.

In the male there are two lateral bursal lobes each with a double-headed bursal ray. Prebursal lateral alae are present. A spicule is apparently absent, or is so lightly cuticularised as to be invisible; the sheath does not project from the body in any specimen; it is not spinose and appears to be voluminous and transversely striated.

The species differs from others from bats in which preanal alae in the male have been described, in the absence of spicules and in having a nonspinous sheath, and in the absence of bacillary bands in the cuticle.

### *Amidostomum biziurac* Johnston and Mawson

(Figs. 4-10)

This species was first described from a single female specimen. A number of males and females have now been obtained from the type host, *Biziura lobata*, in which they occurred in considerable numbers from under the lining of the gizzard in each of two birds examined. The species has been distinguished from others of the genus by the presence of anterior projections around the mouth, and by the nature of the cuticle.

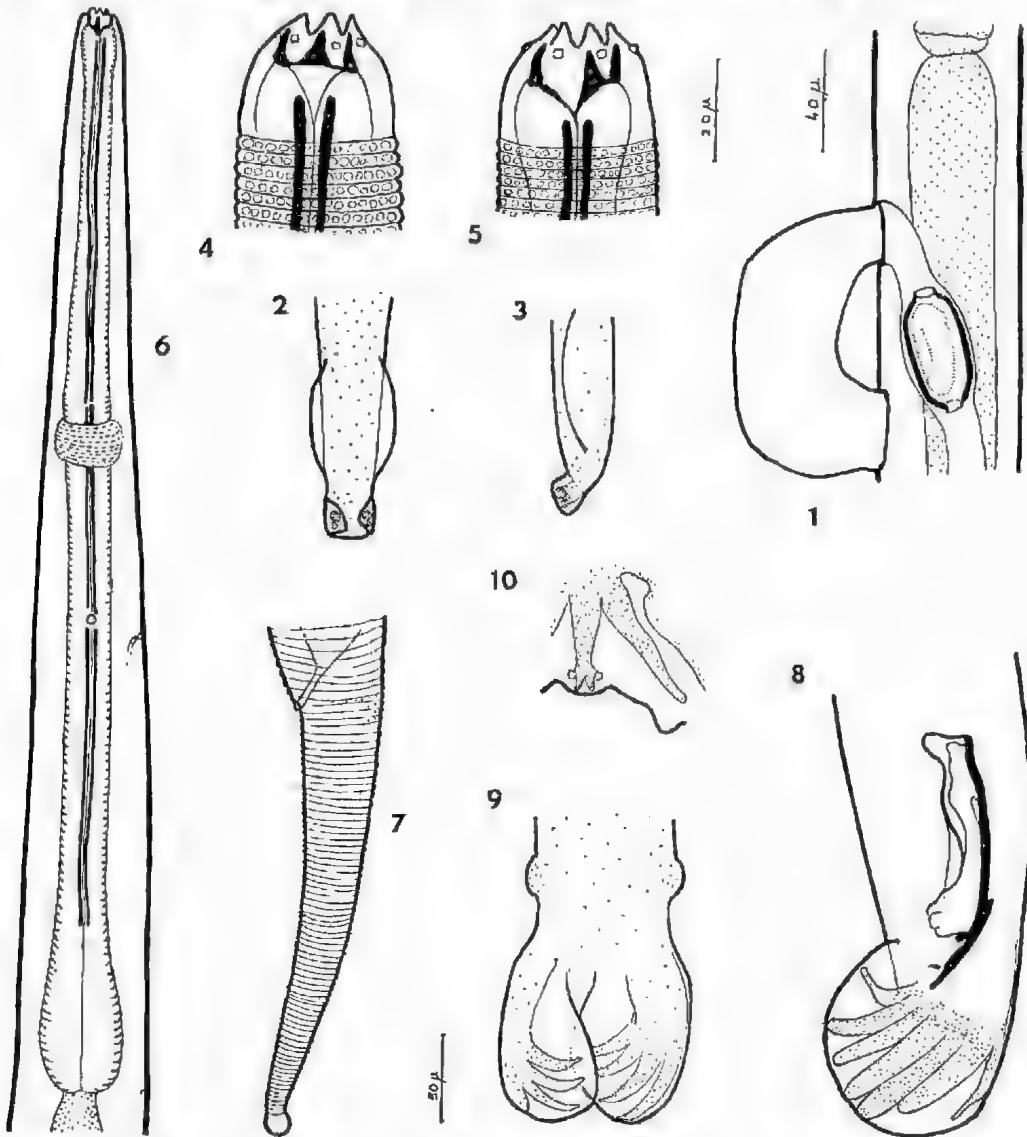
The length of the males is  $7.1-8.1$  mm., that of the females  $9.4-11.5$  mm. The cuticle is annulated, each annule being formed of a row of coarse bosses of more or less equal size; these latter are discontinued in the lateral lines and on the tail of the female. Underneath this outer layer the cuticle is longitudinally striated, but these striae are set obliquely over most of the body, running towards the lateral lines. The anterior end of the worm is rounded and the cuticle not inflated; around the mouth is a ring of six small triangular cuticular outgrowths. Six cephalic papillae are distinct. No epaulette-like structures are present, unless these are represented by the ring of cuticular outgrowths.

The buccal capsule is strongly built and measures in the female  $15\mu$  external, and  $12\mu$  internal, diameter, and  $7-8\mu$  in length. The large dorsal tooth is not noticeably recurved. Other teeth if present are insignificant. The oesophagus is  $530-620\mu$  long in the male,  $600-680\mu$  in the female; it is surrounded by the nerve ring a little in front of its mid-length, and shortly behind this, at almost the same level, are the excretory pore and the minute cervical papillae. In a male in which the oesophagus is  $590\mu$  long, the nerve ring lies  $280\mu$ , the cervical papillae at  $340\mu$ , and the excretory pore at  $345\mu$ , from the anterior end; in a female in which the oesophagus is  $610\mu$  long these distances are respectively  $300\mu$ ,  $350\mu$ , and  $350\mu$ . The oesophagus is lined by several long thick cuticularised bands, referred to by some authors as triturating rods, and these are broken (each possibly projecting as a small tooth) just in front of the nerve ring, where the oesophagus is very slightly swollen. The oesophagus widens slightly in its posterior third and ends in an elongate bulb, into which the triturating rods do not enter.

The female tail,  $210-240\mu$  long, is strongly striated, though not mammillated, and ends in an unstriated bulb. The distance of the vulva from the posterior end of the body is  $1/4.4-1/4.9$  of the total body length. The vulva itself is a wide slit. The eggs are  $70-75\mu$  by  $42-45\mu$ .

The spicules are  $115-130\mu$  long. Each ends in two points of almost equal length, of these the dorsal, sometimes shorter, is the narrower, and the other

wide and membranous. The gubernaculum is  $70\mu$  long. A pair of lateral pre-bursal papillae are present. The bursa is infolded along the outer edge of the lateral lobes so that the tips of the rays are hard to see. A small dorsal lobe is present. The arrangement of the lobes and rays is shown in Figs. 8, 9 and 10.



Figs. 1-10. Figs. 1-3, *Capillaria miniopterae*. 1, vulvar region of female; 2, ventral, and 3, lateral, views of posterior end of male. Figs. 4-10, *Amidostomum biziurae*. 4, dorsal, and 5, lateral, views of head; 6, oesophageal region; 7, tail of female; 8, posterior end of male; 9, ventral view of bursa; 10, dorsal ray. Figs. 1, 2, 3 and 8 to same scale; Figs. 4 and 5 to same scale; Figs. 6, 7, 9 and 10 to same scale.

#### The genus NICOLLINA Baylis, 1930

Baylis in 1930 (p. 17) described two species of a new genus from echidnas. He stated that neither of them appeared to be that recorded (unnamed) by Nicoll (1914), because Nicoll described the worms as retaining their coiled

shape in hot alcohol, whereas those of Baylis were not coiled. Cameron in 1931 (p. 153) added another species to the genus, from a marsupial *Sarcophilus harrissi*, and stated that this species assumes the tightly coiled habit when preserved.

Of two echidnas recently dissected in this department, only one was parasitised, and this had two species, one coiled tightly in a long spiral and the other loosely curved. The latter are identified with one of the species described by Baylis, but the former appears to be so far undescribed, and may be that recorded by Dr. Nicoll.

***Nicollina echidnae* Baylis, 1930**

(Figs. 11-12)

A number of specimens were obtained from *Tachyglossus aculeata* from Kangaroo Island. Six of each sex were measured. The specimens agree in most points with those described from echidnas from Queensland. The males are about the same size, the females rather longer, 5.2-6.5 mm. and 6.7-8.1 mm. long respectively. The body bears one lateral ala as described by Baylis and the cuticle posterior to the cephalic inflation is longitudinally as well as transversely striated; it is, however, raised into broken longitudinal crests, of which there are about two at the anterior end and more in the wider part of the body.

The eggs are 30-35 $\mu$  by 70-80 $\mu$ , whereas those measured by Baylis are 55-75 $\mu$  by 30-33 $\mu$ . These are the only points in which the new specimens differ from the description given by Baylis. The spicule shape and length (340-390 $\mu$ ) and the dorsal ray of the bursa, are exactly as described. It is possible that the Queensland specimens were younger and the longitudinal crests were not developed.

The mouth is surrounded by six prominent lips, not figured or described by Baylis.

***Nicollina cameroni* n. sp.**

(Figs. 13-16)

A large number of specimens were taken from *Echidna aculeata* from Kangaroo Island. In the closely coiled habit of the body the species resembles *N. sarcophilus* Cameron, but it differs from this species in the presence of two lateral alae and in the shape of the spicules and of the dorsal ray. It is distinguished from *N. echidnae* Baylis by the size of the dorsal tooth, the absence of marked longitudinal crests, the presence of two lateral alae, the spicule length and the shape and the coiled habit of the body, the last being distinct in both living and fixed worms. The presence of the two lateral alae and the exact shape of the spicules do not agree with the original description of the genus, but it is thought that the species nevertheless belongs among *Nicollina* species.

The males are 4.5-5.2 mm. long, the females 6.2-7.0 mm. The inflated nuchal cuticle is coarsely striated and extends 95-115 $\mu$  from the anterior end of the worm. The succeeding cuticle is strongly but closely striated, and in some parts of some specimens is finely rugose. There is some appearance of longitudinal banding, in that the striae are less obvious at intervals, but the cuticle is not raised into crests as in *N. echidnae*. The six lips are distinct. The buccal capsule is well cuticularised, and the tooth is small, lying at the entrance to the oesophagus. The oesophagus widens only very slightly at the posterior end; it is 310-440 $\mu$  long in the male, 450-490 $\mu$  in the female.

The female tail is 140-150 $\mu$  long with a terminal spine and two small sub-terminal prominences. The vulva is 700-750 $\mu$  from the posterior end; the uteri are opposed; the eggs are 70-77 $\mu$  by 37-38 $\mu$ .

The bursa is particularly difficult to unroll, and its dorsal region is obscured by granular inclusions; a distinct dorsal lobe is absent. The arrangement of the bursal rays is shown in Figs. 15-16; the dorsal ray resembles that of *N. echidnae*, except that the first branches are longer. In some specimens there seems to be three final branches instead of two, but this appearance may be due to the granular nature of the bursa. The spicules are 400-550 $\mu$  long, slender and needle-like, without alae. The tips are different, however, the right-hand one ending in a ball point and the left-hand one in a simple point. A lightly cuticularised elongate gubernaculum is present.

*Nycteridostrogylus unicoloris* Baylis, 1930

(Figs. 17-19)

Five adult worms were taken from *Miniopteris blepotis* from Naracoorte, South Australia, and seven males, two females, and three immature males, from the same host specimens from Canungra, Queensland.

The adults, from the small intestine of the host, agree very well with those described by Baylis. The measurements are as follows: Length of males 4.5-8.3 mm., of females 4.5-6.5 mm.; length of cuticular inflation 35-70 $\mu$ ; length of oesophagus 350-500 $\mu$  in both sexes, with the nerve ring 150-155 $\mu$  from the anterior end and the cervical papillae and excretory pore at the same level. The female tail is 70-80 $\mu$  long. The spicules are 510-600 $\mu$  long. In one broken specimen the tips are distinct; they are provided with a striated flange extending from near the proximal end nearly to the tip; the spicule is hollow, more or less cylindrical, and the tip does not appear to be split into several processes, or, if so, these remain closely applied to one another.

The three immature males, probably 4th stage larvae, were from cysts in the mesentery of the host. In the two shortest (2.8, 3.0 mm.), neither oblique cuticular ridges nor cephalic inflation are present, and these are only referred to the species by their association with the third (4.0 mm.), apparently slightly older, specimen (Fig. 19), in which these ridges and the cephalic inflation are distinct. In all three the rudiment of the bursa is present, and in the longest there is some sclerotisation of the spicule.

*Austrostrongylus thylogale* Johnston and Mawson, 1940

From *Setonix brachyura*, Rottnest Island, Western Australia.

Mr. Shelley Barker of the Zoology Department of the University of Western Australia, who collected these specimens, states that the species is exceedingly common in this host, up to 6000 worms having been collected from one animal.

The specimens are larger than those recorded from *Thylogale eugenii* from Kangaroo Island, but the proportions and appearance are similar. The males are about 6 mm. long, the female up to 7 mm. The spicules are 4.5 mm. long and in most specimens a small oval gubernaculum is visible, 20-30 $\mu$  long. The eggs are also larger, 90 $\mu$  by 45 $\mu$ .

It is possible that the difference in size of the worms from the two localities is constant and connected with the isolation of each on an off-shore island for a considerable time. There is no other difference between them; it is unnecessary to propose a new species or variety. A gubernaculum is not mentioned in the original description, but it is very small and easily missed in a long preserved specimen; those from Western Australia are newly collected and very well preserved, and even in these the structure is not always clear.

*Molinostrongylus dollfusi* n. sp.

(Figs. 20-24)

From *Miniopteris blepotts* from Canungra, Queensland, and from Naracoorte, South Australia.

This new species is very close to *M. panousi* Dollfus, 1954. It is distinguished from this species by the length of the spicule and by its shape as well as by the presence of a well-developed dorsal lobe on the bursa and by the longer cephalic inflation. The worms from South Australian hosts are smaller than those from Queensland, but are believed to belong to the same species; their measurements follow those of the Queensland ones in parentheses. The drawing are taken from Queensland specimens.

The males are 3.5-3.7 mm. long (2.6-2.9 mm.) and the females 5.0-5.2 mm. (3.4-3.9 mm.). The cuticle is finely striated longitudinally and transversely; the lateral alae start shortly behind the cephalic inflation and extend to the vulva in the female, behind which they are narrower and resemble the other longitudinal bands. In the male they extend almost to the bursa. In addition to the lateral alae there are a number of finer longitudinal ridges, four on each side, in the posterior oesophageal region, and seven on each side further back. They extend to the tail region in both sexes. The cephalic papillae are not distinct. The cephalic inflation is 50-55 $\mu$  long (48 $\mu$ ) in the male and 60 $\mu$  (50 $\mu$ ) in the female.

The length of the oesophagus is 300 $\mu$  (300 $\mu$ ) in the male and 350-360 $\mu$  (320-330 $\mu$ ) in the female. The nerve ring is 160-170 $\mu$  (170 $\mu$ ) and the excretory pore 220-230 $\mu$  (160-170 $\mu$ ) from the head in the male. The cervical papillae are at the same level as the excretory pore.

The female tail ends in five conical processes, three long and two short, and a spike 35 $\mu$  long. Including the spike, the tail length is 60-70 $\mu$  (50-55 $\mu$ ). The vulva is not prominent, and lies 1.3-1.5 mm. (0.9-1.0 mm.) from the posterior end of the worm. The eggs are 90-100 $\mu$  by 45-50 $\mu$  in the South Australian specimens; none were present in those from Queensland.

The spicules in all specimens have a very distinct and constant curvature when seen in lateral view (Fig. 22). The anterior end of the gubernaculum is bent dorsal at right angles to the longitudinal axis of the posterior, longer, part. The spicules are alate, the alae extending along the length of the spicule nearly to the tips, where the spicule bifurcates, ending in two prongs, of which the shorter, more median, is bent back into a hook, and the longer is gently curved. The spicule length is 150-160 $\mu$  (130-140 $\mu$ ), that of the gubernaculum 50 $\mu$  (40 $\mu$ ). The lateral lobes of the bursa are lined with hooks, of which the larger ones are postero-dorsal in position and the smaller ones ventral and anterior. The dorsal lobe is well developed and trilobed. The size and position of the rays is best seen in Fig. 23. Prebursal papillae are present.

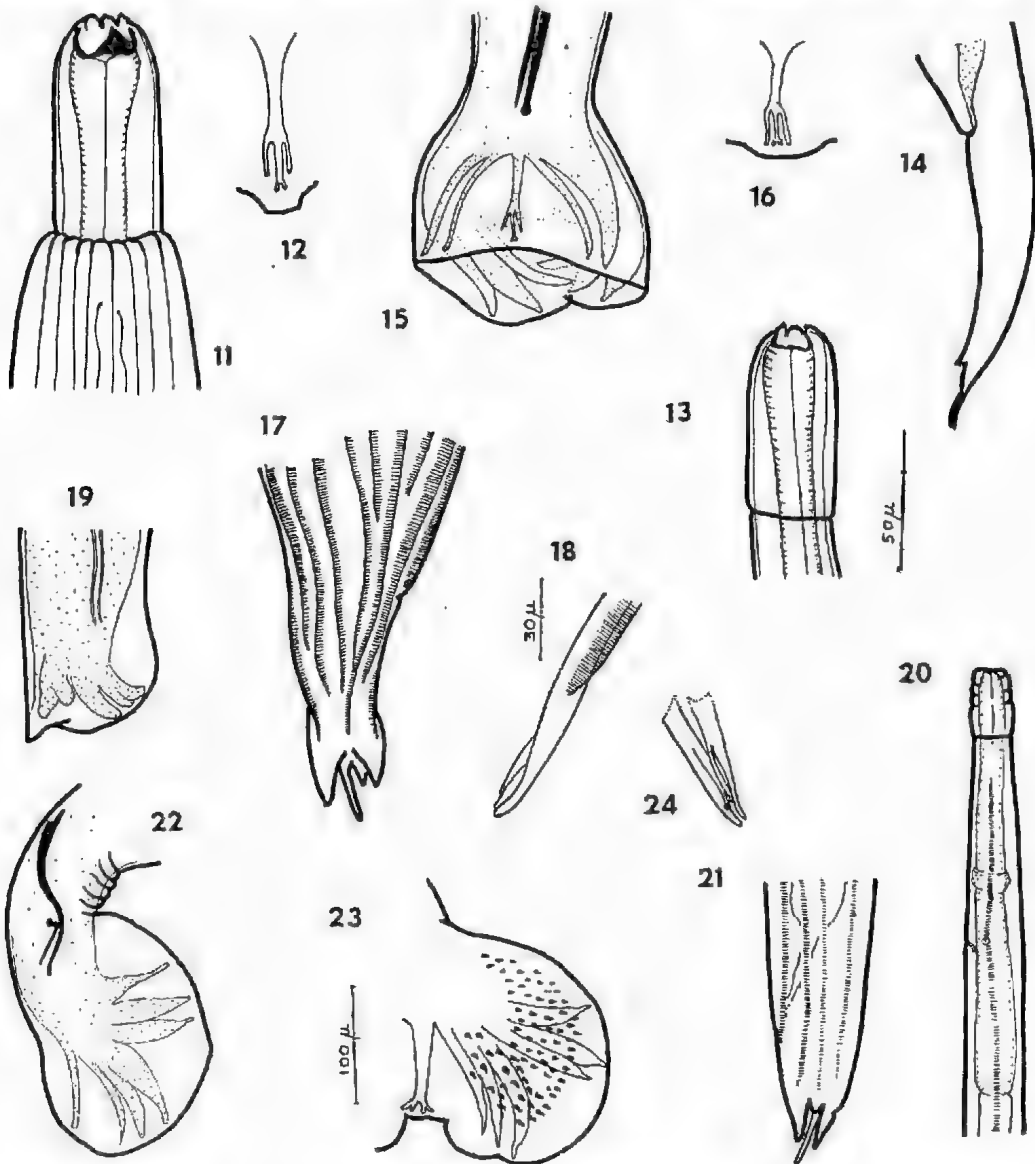
*Pharyngodon australis* Johnston and Mawson, 1942

From the large intestine of *Tiliqua scincoides*, Brisbane.

The measurements of the new material are as follows: Male—maximum breadth 130-160 $\mu$ ; length of body 1.8-2.3 mm., of oesophagus 200-250 $\mu$ ; distance of excretory pore from anterior end 530-640 $\mu$ ; length of tail spine 40-70 $\mu$  (less than length of bursa); spicule not chitinated. Female—breadth 230-250 $\mu$ ; length of body 3.2-3.8 mm., of oesophagus 300-400 $\mu$ ; of tail 540-720 $\mu$ ; distance of anterior end from excretory pore 500-550 $\mu$ ; of vulva 600-650 $\mu$ .

*P. australis* was separate from *P. tiliquae* Baylis by the size of the body and of the eggs, the position of the excretory pore and vulva in the female, and

the length of the tail spike in the male. In this new material, the size, and the positions of vulva and excretory pore agree with *P. tiliquae*, eggs are absent,



Figs. 11-24. Figs. 11-12, *Nicollina echidnae*. 11, anterior end of male; 12, dorsal ray. Figs. 13-16, *Nicollina cameront*. 13, anterior end; 14, posterior end of female; 15, bursa; 16, dorsal ray. Figs. 17-19, *Nycteridostrogylus unicolitis*. 17, posterior end of female; 18, distal ends of spicules; 19, posterior end of immature male. Figs. 20-24, *Molinosstrongylus dollfus*. 20, oesophageal region; 21, posterior end of female; 22, posterior end of male; 23, part of bursa; 24, tips of spicules. Figs. 11, 12, 17, 18 and 24 to same scale; Figs. 13, 14, 16 and 21 to same scale; Figs. 15, 20, 22 and 23 to same scale.

and the tail of the male agrees in every particular with *P. australis*. The author, having seen specimens of *P. tiliquae*, prefers to keep *P. australis* separate, at least until larger numbers of specimens are available.



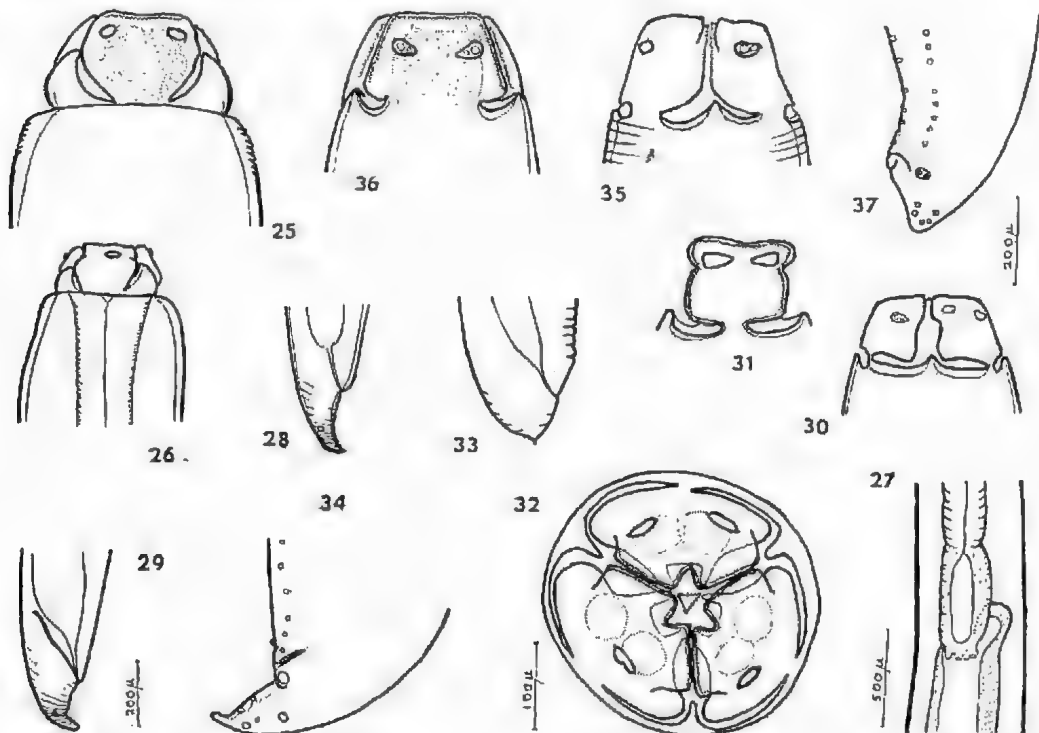
**Porrocaecum (Laymanicaecum) sp.**

(Figs. 25-29)

From *Emusium halloti*, Shark Bay, Western Australia.

Only larval worms are present, although in at least two the rudiments of the spicules are to be seen. The parasite is apparently common in the scallop beds in this region. It is assumed that the adult will be found in some predator of the mollusc, such as rays, from these waters.

The specimens are allotted to the genus *Porrocaecum* because of the presence of interlabia, elongate oesophageal ventriculus, and intestinal caecum. The subgenera *Porrocaecum* s. str. and *Laymanicaecum* Mozgovoy are separated by the presence or absence of a gubernaculum, a distinction impossible to make in the present case. However, as the former is found as adults in birds, and the latter in elasmobranchs, it is assumed that the scallop parasites belong to (*Laymanicaecum*). Only two species have so far been allotted to the subgenus, *P. laymani* Mozgovoy and *P. pastinaceae* (Rud.) sensu Dollfus and Desportes, 1945 (Campana-Rouget, 1955, 829).



Figs. 25-37. Figs. 25-29, *Porrocaecum* (*Laymanicaecum*) sp. 25, dorsal, and 26, lateral, views of head; 27, region of ventriculus; 28, posterior end; 29, tail of young male. Figs. 30-34, *Amplicaeum mackerrasae*. 30, lateral view of head; 31, dorsal lip; 32, en face view of head; 33, tail of female; 34, tail of male. Figs. 35-37, *Ophidascaris* sp. 35, sublateral, and 36, dorsal, views of head; 37, tail of male. Figs. 25, 32, 35 and 36 to same scale; Figs. 26, 30 and 37 to same scale; Figs. 27, 28, 33 and 34 to same scale.

The length is up to 30-43 mm., the maximum breadth  $750\mu$ . The oesophagus is 2.9 mm. long (43 mm. specimen), including the ventriculus which is  $600\mu$  long,  $250\mu$  wide. The intestinal caecum is very short, no more than half the length of the ventriculus; it may not be visible when viewed so that it is behind

the ventriculus, but when the specimen is rolled over it is clearly seen as a hollow diverticulum. It is possible that the length in the adult is greater.

The shape of the lips is shown in the figures. Each bears a row of teeth which in en face view show a rounded rather than pointed profile. The excretory pore lies at the base of the ventral interlabium. The nerve ring lies  $550\mu$ , and cervical papillae  $750\mu$ , from the anterior end.

The conical tail is  $300\mu$  long. In specimens in which a rudimentary spicule can be seen, it is  $400\mu$  long (Fig. 29). At about midlength of the tail, in all specimens, are two large lateral papillae. These are presumably the phasmids, and they are present in the male as well as the female larvae.

***Amplicaecum mackerrasae* nom. nov.**

(Figs. 30-34)

Two female, one male, and several immature specimens were taken from  
*Vutanus varius*, Mt. Nebo, Queensland.

The presence of an intestinal caecum, distinct in whole mounts of the immature specimens and on dissection of the adult, showed that the species belongs to the genus *Amplicaecum*, but in other features closely resembles that described as *Ophidascaris varani* Johnston and Mawson (1947, 23). The type (and only) specimen of *O. varani* has been re-examined and a very thin intestinal diverticulum, half of the length of the oesophagus, found to be present. The species is therefore transferred to *Amplicaecum* but as the specific name in this combination is preoccupied a new name is proposed, *A. mackerrasi*. The length given in the original description, 7 mm., is a misprint for 70 mm.

The species lies with those of the genus in which the vulva is anterior to the midbody, the intestinal caecum about half the length of the oesophagus, i.e. *A. brumpti*, *A. numidica*, *A. cacopi*, and *A. schoutei*. It is distinguished from all of these by the greater length of the spicules as well as by other small points.

The length of the male is 67 mm., that of the female 102-108 mm. The shape of the lips and configuration of the head is shown in Figs. 30 to 32. The length of the oesophagus is 6 mm. in the male, 7 mm. in the female, and that of the intestinal caecum is a little less than half this. The nerve ring is at one-eighth and one-ninth of the oesophageal length in the female and male respectively.

The vulva lies in front of the middle of the body, 40-42 mm. from the head. The eggs are about  $90\mu$  by  $60\mu$  in size. The tail of the female is rounded but ends in a small spine. It is  $80\mu$  long, less than the anal breadth.

The conical tail of the male is  $60\mu$  long. There are 33 pairs of pre-anal papillae and six pairs of post-anal, arranged as in Fig. 34. The spicules are 1.3 mm. long.

***Ophidascaris* sp.**

(Figs. 35-37)

From *Amphibolurus barbatus*, from West Burleigh, Queensland, in the retroperitoneal tissues.

Only one male is present. This is 56 mm. long; the body tapers in the anterior half, the greatest breadth,  $780\mu$ , being behind the mid-length. The lips have well developed dentigerous ridges. The interlabia are very short. The oesophagus is 3.1 mm. long, the nerve ring is at  $520\mu$  from the anterior end. The specimen was dissected and no intestinal caecum could be found.

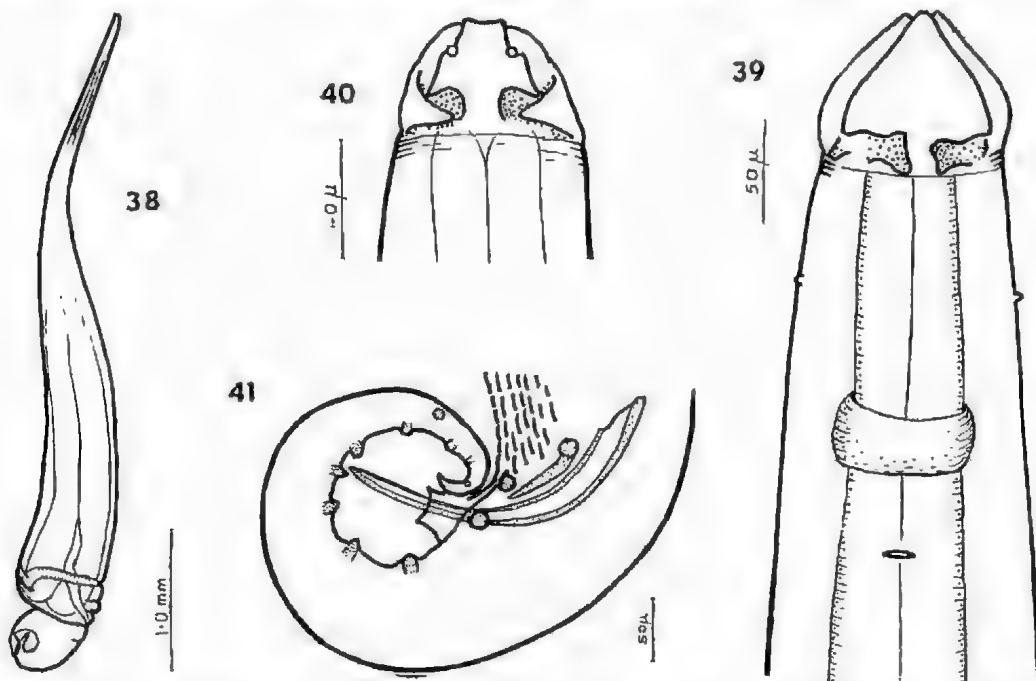
The tail is very short,  $150\mu$ , while the anal breadth is  $210\mu$ . There are 43 pairs of pre-anal papillae, one pair of double-headed adanal, and five pairs of post-anal, clustered on the second half of the tail. The spicule is 4.38 mm. long; no gubernaculum was seen.

***Hedruris longispicula* n. sp.**

(Figs. 38-41)

From *Lygosoma challenger*, from Springbank, South Queensland.

The males reach 3.0 mm. in length,  $115\mu$  maximum breadth. The females are 4.0-5.0 mm. long, the width of the anterior part of the body (at level of the nerve ring)  $130-190\mu$ , and that at the widest part  $550-600\mu$ . The cuticle is finely striated transversely and beneath these coarser longitudinal striae are seen, in both sexes. The head is short and there are no balloon-like inflations posterior to the lips. The length of the oesophagus is  $550\mu$  in the male, and  $900\mu$  in the female, and the distance from the anterior end of the cervical papillae, nerve ring, and excretory pore are respectively  $130-140\mu$ ,  $180-200\mu$ , and  $230-260\mu$  in the female, and  $150\mu$ ,  $170\mu$ , and  $280\mu$  in the male. The vulva is  $750\mu$  from the posterior end of the worm. The eggs are  $55\mu$  by  $25\mu$ , without lateral protuberances. The anus is  $500-550\mu$  from the posterior end.



Figs. 38-41, *Hedruris longispicula*. 38, entire female; 39, head of female; ventral view; 40, head of male, lateral view; 41, tail of male.

In the male the tail is  $350\mu$  long and is coiled in two to three rings, for most of which region the ventral surface anterior to the anus bears broken longitudinal ridges. The caudal alae extend from just in front of the anus to near the tip of the tail and support eleven papillae on each side. The spicules are  $300\mu$  long. A short ( $70\mu$ ) chitinised bar lying anterior to the spicule appears to be a gubernaculum.

In the shape of the head and lips the species is closest to *H. tiara* Van Cleave & Mueller; it differs from this in the position of the vulva and the length of the spicule. In the female the ratio between the maximum body width and that in the oesophageal region is greater than in any other species, though this may be at least in part due to their being at a more advanced stage of egg-bearing than the types of some other species. The spicules are almost as long as the tail, whereas in only one other species in which the male is described (*H. spinigera* Baylis) is it more than two-thirds of the tail length, and in other species it is half the tail length or less.

***Abbreviata bancrofti* (Irwin-Smith)**

From *Aspidites melanocephalus*, from Cairns.

The type host of the *Abbreviata bancrofti* is an Australian gecko, *Gymnodactylus platurus*, and the species has not been recorded since. The specimens from the snake, one male and two females, agree very closely in characters of the head and tail and reproductive system, with Irwin-Smith's description, and cannot be allotted to any other species. It was pointed out by Chabaud (1956, 41) in his valuable revision of the physalopterans from reptiles that *P. oligopapillata* (Kreis, 1940) is very close to *A. bancrofti*.

The measurements of the new specimens are as follows: Male—18.7 mm. long, oesophagus 2.6 mm. long (a seventh body length), spicules 1.25 mm., and 0.3 mm. long; female—14.7-18.3 mm. long, oesophagus 2.3-2.5 mm. long (a sixth to a seventh body length), distance of vulva from anterior end 3.9-4.5 mm., a quarter of the body length, eggs 43 $\mu$  by 23-26 $\mu$ .

#### ACKNOWLEDGMENTS

The specimens described in this paper were very kindly sent for identification from various institutions: those from Queensland and New South Wales by Dr. M. J. Mackerras (Queensland Institute of Medical Research), from the Western Australian scallop by Dr. K. Sheard (C.S.I.R.O., Fisheries Division); from the wallaby by Mr. Shelley Barker (Zoology Department, University of Western Australia). Other material was collected by colleagues of this University.

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# CYTOLOGICAL STUDIES IN THE GENUS *DANTHONIA*

BY K. ABELE

## Summary

Counts have been made of the chromosomes of 28 Australian species of *Danthonia*. Counts of 24, 42, 48, 72 and 96 somatic chromosomes were recorded. A study of stomatal lengths showed this character to be highly correlated with the level of polyploidy except in a few species. Except in three species, increasing levels of polyploidy are associated with increased hairiness of the lemma. No other conspicuous morphological character showed any relationship with the level of polyploidy. Two species displayed intraspecific polyploidy, viz. *D. caespitosa* ( $2n = 24, 48$  and  $72$ ) and *D. longifolia* ( $2n = 24$  and  $48$ ). The number of collections of *D. longifolia* was inadequate for an effective examination of the geographic distribution of the two chromosome races. Characteristics such as floret morphology, stomatal length and geographic distribution were not entirely satisfactory as criteria for distinguishing the chromosome races of *D. caespitosa*. The distribution and the interspecific relationships of polyploid levels in the genus *Danthonia* are reviewed.

# CYTOLOGICAL STUDIES IN THE GENUS *DANTHONIA*.

by K. ABELE\*

[Read 12 June 1958]

## SUMMARY

Counts have been made of the chromosomes of 28 Australian species of *Danthonia*. Counts of 24, 42, 48, 72 and 96 somatic chromosomes were recorded. A study of stomatal lengths showed this character to be highly correlated with the level of polyploidy except in a few species.

Except in three species, increasing levels of polyploidy are associated with increased hairiness of the lemma. No other conspicuous morphological character showed any relationship with the level of polyploidy.

Two species displayed intraspecific polyploidy, viz. *D. caespitosa* ( $2n = 24, 48$  and  $72$ ) and *D. longifolia* ( $2n = 24$  and  $48$ ). The number of collections of *D. longifolia* was inadequate for an effective examination of the geographic distribution of the two chromosome races. Characteristics such as floret morphology, stomatal length and geographic distribution were not entirely satisfactory as criteria for distinguishing the chromosome races of *D. caespitosa*.

The distribution and the interspecific relationships of polyploidy levels in the genus *Danthonia* are reviewed.

## INTRODUCTION

Some 100 species of *Danthonia* are known in temperate and sub-tropical parts of the world; many are valuable fodder grasses. The papers of Trumble (1927), Richardson, Trumble and Shapter (1931), Trumble and Davies (1931), and Cashmore (1932) deal with the taxonomy and agronomic value of the Australian species of *Danthonia*; eleven new species of Australian *Danthonia* have been described by Vickery (1950), and more recently a revision of the Australian species has been carried out by the same author (Vickery, 1956).

Several studies dealing with chromosome numbers in *Danthonia* have been made in the United States and South Africa (see 'Discussion') and these have included some Australian species. The present study was designed to examine chromosome numbers and the possible occurrence of intraspecific polyploidy in a range of Australian species.

The plants studied were collected from natural Australian habitats as plants or seed. The individual plants were numbered, and specimens of most of them are preserved in the herbarium of the Waite Agricultural Research Institute, Adelaide.

## CYTOLOGICAL TECHNIQUE

The root tips for cytological examination were pretreated for four hours in a 0.003 mol. solution of 8-hydroxy-quinoline (Tjio and Levan, 1950), and fixed in acetic acid-alcohol. The pretreatment was advantageous in spreading the metaphase chromosomes, so that even in cases of polyploidy the counting and study of chromosomes presented few difficulties. Root tips were stained in bulk using Feulgen.

Generally, there is no difficulty in germinating seed of *Danthonia*. The dormancy shown by some species following harvesting can be broken by ex-

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posing the seed, previously soaked in water, to a temperature of 2-3° C. for a week. An exception is the seed of *D. bipartita*, which is difficult to germinate.

## RESULTS

### 1. Chromosome numbers and morphology

The Australian species of *Danthonia* examined in this study have 24, 42, 48, 72 or 96 chromosomes (Table 1), but in contrast with some species from overseas none of the Australian material had 12 or 36 chromosomes.

TABLE 1.  
Numbers of chromosomes in Australian species of *Danthonia*.

Species	No.	Species	No.
<i>D. alpicola</i> J. W. Vickery	24	<i>D. longifolia</i> R. Br.	24
<i>D. auriculata</i> J. M. Black	24		48
<i>D. bipartita</i> F. Muell.	72	<i>D. nudiflora</i> P. F. Morris	24
<i>D. caespitosa</i> Gaubl.	24	<i>D. occidentalis</i> J. W. Vickery	24
	48	<i>D. pallida</i> R. Br.	72
	72	<i>D. penicillata</i> (Labill) Beauv.	24
<i>D. carphoides</i> F. Muell.	24	<i>D. pilosa</i> R. Br.	24
<i>D. clelandii</i> J. W. Vickery	48	<i>D. pilosa</i> var. <i>paleacea</i> J. W. Vickery	24
<i>D. duttoniana</i> A. B. Cashmore	24	<i>D. procera</i> J. W. Vickery	96
<i>D. eriantha</i> Lindl.	48	<i>D. purpurascens</i> J. W. Vickery	72
<i>D. frigida</i> J. W. Vickery	42	<i>D. racemosa</i> var. <i>obtusata</i> F. Muell.	24
<i>D. geniculata</i> J. M. Black	48	<i>D. richardsonii</i> A. B. Cashmore	48
<i>D. induta</i> J. W. Vickery	72	<i>D. semiannularis</i> (Labill) R. Br.	24
<i>D. laevis</i> J. W. Vickery	48	<i>D. setacea</i> R. Br.	24
<i>D. linkii</i> Kunth	24		
<i>D. linkii</i> var. <i>julea</i> J. W. Vickery	72		

The chromosomes of all the above species are uniform in size and morphology. Length is of the order of  $4\mu$  except *D. bipartita*, which are  $1-2\mu$ .

No morphological features such as differences in size, secondary constrictions or trabants have been seen. In several cases small particles attached to the end of the chromosome were observed staining in Feulgen and closely resembling trabants, but as they appear rarely and irregularly they could not be definitely identified as such. This absence of morphological differences accords with the work of other authors except De Wet (1953). Calder (1937, p. 5, fig. 7) draws two somatic chromosomes of *D. setifolia* with apparent trabants, but there is no mention of them in the text.

The bivalents at diakinesis in pollen mother cells are about  $3\mu$  long, with the exception of the bivalents of *D. bipartita*, which are about  $1\mu$  long. The diakinetid chromosomes in the pollen mother cells show bivalents only; no univalents or multivalents have been observed at any stage.

For all species, again with the exception of *D. bipartita*, a complete terminalization of the chiasmata of the bivalents by diakinesis is characteristic. No terminalization of the chiasmata was observed in *D. bipartita*.

### 2. Measurements of stomata

Stomatal size is widely used as a criterion for assessing the degree of polyploidy. It is considered to be a better index of the chromosomal number than the size of the pollen grains (Müntzing, 1937).

(a) In order to determine the extent to which length of the stomata in *Danthonia* may be influenced by environmental factors two species of *Danthonia*, *D. duttoniana* and *D. richardsonii*, were each grown under different environ-

TABLE 2.

Measurements of stomata in two species of *Danthonia* grown under different environmental conditions (Figures for individual treatments are means of measurements of 100 stomata in microns).

Species	Position on leaf	Growing in field	Growing in Glasshouse								Mean of all treatments	
			Water and light normal	Water restricted light normal	Water normal light restricted	Water and light restricted	Water normal (Mean of light treatments)	Water restricted	Light normal (Mean of water treatments)	Light restricted		
<i>D. duttoniana</i>	Tip	$(\pm 0.20)^a$ 35.7	37.8	$(\pm 0.20)^a$ 35.6 37.6 36.6	35.1 38.1 36.7	36.7 37.1 33.9	$(\pm 0.14)^c$ 36.4 37.6 37.3	36.2 37.3 35.2	$(\pm 0.14)^c$ 36.7 37.3 37.3	35.9 37.6 35.3	$(-0.10)^a$ 36.3 37.5 36.3	
	Middle											
	Base											
	Mean		37.6	$(\pm 0.11)^b$ 36.6	36.6	35.9	$(\pm 0.08)^d$ 37.1	36.2	$(\pm 0.08)^d$ 37.1	36.3	36.7	
<i>D. richardsonii</i>	Tip	$(\pm 0.23)^a$ 42.1	39.7	$(\pm 0.23)^d$ 39.3 41.7 40.6	41.9 42.2 40.8	38.7 39.7 37.7	$(\pm 0.16)^a$ 40.8 41.5 40.8	39.0 40.7 39.2	$(\pm 0.16)^a$ 39.5 41.2 40.7	40.3 40.9 39.3	$(\pm 0.12)^a$ 39.9 41.1 40.0	
	Middle											
	Base											
	Mean		40.5	$(\pm 0.13)^b$ 40.5	41.6	38.7	$(\pm 0.09)^d$ 41.1	39.6	$(\pm 0.09)^d$ 40.5	40.2	40.3	
Significant Differences:			<i>D. duttoniana</i>								<i>D. richardsonii</i>	
			(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
	5%		0.54	0.31	0.38	0.22	0.27	0.64	0.37	0.45	0.26	0.32
	1%		0.72	0.41	0.51	0.29	0.36	0.84	0.48	0.59	0.34	0.42
0.1%		0.91	0.53	0.65	0.37	0.46	1.07	0.62	0.76	0.44	0.54	

mental conditions and the length of their stomata measured. All plants were obtained by dividing a single parent plant grown from seed.

One plant from each species was grown in the open and was well watered. All the other plants were grown in pots in an open-sided glasshouse. Two plants of each species were grown in full glasshouse light, while another pair was covered with a perforated zinc iron cage admitting about 50 per cent. of the light. One plant of each pair was well watered, while the other was given only as much water as was necessary to prevent killing. The growth of the plants in the glasshouse was slightly retarded compared with the control plants in the open, while plants receiving limited water showed a further reduction in size.

The stomata on the upper surface of the leaf are restricted to the longitudinal grooves whilst the lower surface is ungrooved and often has fewer stomata, in some species even none. Sections from the upper surface were used for the measurements.

The leaf subtending the inflorescence was called the first leaf, the other leaves being numbered accordingly. In *D. duttoniana* the stomata of the first leaf, especially when this leaf was small, were sometimes shorter than the stomata of the third leaf by 2-3 $\mu$ . In *D. richardsonii* where the leaves are more robust, this difference could not be observed.

The third leaf was used for the comparison of stomata developing under various environmental treatments. The length of stomata near the base of the lamina, in the middle and near the tip, were measured. In all cases the lengths of 100 stomata were measured. The results are shown in Table 2.

Restriction of water or light supply led to significant but small decreases in the length of the stomata. The reduction due to water restriction was 2.4 per cent. in *D. duttoniana* and 3.7 per cent. in *D. richardsonii*. Stomata were larger in the central position on the leaf than at the base or tip.

The data establish clearly that differences in stomatal size due to grossly varying environmental conditions or to position on the leaf do not exceed values of the order of 5 per cent. Substantially greater differences between plants—even between those grown under different environmental conditions—may be properly regarded as being due to differences of genetic constitution.

(b) To study the correlation of the stomatal length with the chromosome number, measurements were made on all species included in this study. These were grown at the Institute under field conditions with the exception of *D. bipartita*. Measurements of the stomata of this species were made on the leaves of mature plants brought from the John Mortlock Experimental Station at Yudnapinna, 250 miles to the north of Adelaide, where the mean annual rainfall (9in.) is much lower than at the Waite Institute (25in.).

In all cases the leaves taken for stomatal measurements were from plants whose chromosomes had been counted. Stomata from the middle of the lamina of the third leaf were selected for measurement.

The variation within most species was small. For instance, the range of variation in stomatal size between plants of *D. purpurascens* was 60.7 $\mu$ -61.4 $\mu$ , in *D. linkii* var. *fulva* 41.4 $\mu$ -42.5 $\mu$  and in *D. semianularis* was 38.2 $\mu$ -40.2 $\mu$ .

Wide variation, however, was encountered in two species. Plants of *D. caespitosa* having the same chromosome number,  $2n = 48$ , showed a range from 42.1 $\mu$  to 53.2 $\mu$ . The variation is also wide in *D. bipartita* which showed values among six plants of 32.4, 33.4, 31.0, 37.0, 37.8 and 42.6 $\mu$ . These ranges of variation in stomatal size in plants of *D. caespitosa* having 48 chromosomes (11.3 $\mu$ ), and in *D. bipartita* (10.2 $\mu$ ) are each about as great as that within the entire group of 10 species having 48 chromosomes (51.8 $\mu$ -41.2 $\mu = 10.6\mu$ )

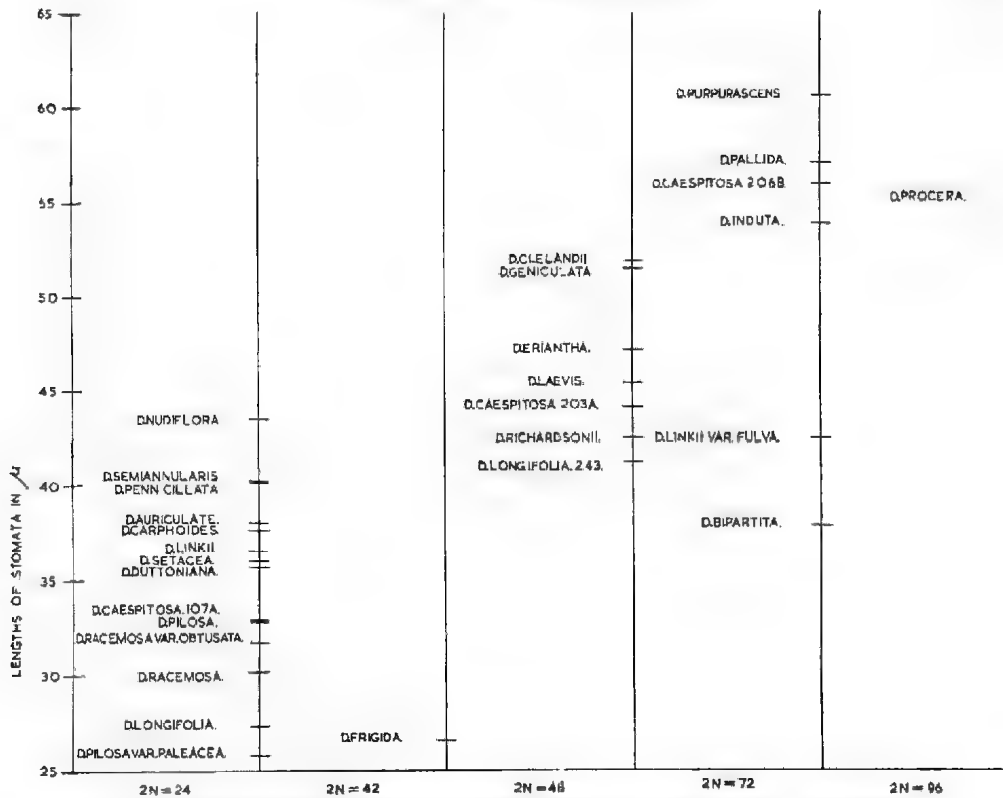


Fig. 1.—Mean stomatal lengths plotted against the chromosome numbers of Australian species of *Danthonia*.



Fig. 2.—The distribution of three chromosome races of *D. caespitosa*. Reference: hollow circles = 24 chromosome *D. caespitosa*; full black circles = 48 chromosome *D. caespitosa*; crosses = 72 chromosome *D. caespitosa*. Each symbol covers one habitat from which the plant was collected for chromosome counting, except the cross near Adelaide which covers 5 habitats. The position of the symbols in the crowded areas is approximate only.

TABLE 3.  
The relationship between the arrangement of hairs on the lemma body and the level of polyploidy in Australian *Danthonia* species.

Arrangement of hairs on the lemma body	2n=24	2n=48	2n=72	2n=96
Only lower ring complete	<i>D. racemosa</i> , <i>D. nudiflora</i> , <i>D. pilosa</i> , <i>D. pilosa</i> var. <i>paleacea</i> , <i>D. penicillata</i>			
Only upper ring complete	<i>D. semianularis</i> , <i>D. occidentalis</i> , <i>D. longiflora</i>	<i>D. laevis</i> <i>D. longiflora</i>		
2 complete transverse rings	<i>D. alpicola</i> , <i>D. auriculata</i> , <i>D. duttoniana</i> , <i>D. setacea</i> , <i>D. caespitosa</i>	<i>D. eriantha</i> <i>D. caespitosa</i>	<i>D. caespitosa</i>	<i>D. proceru</i>
2 complete transverse rings with a few scattered hairs between		<i>D. clelandii</i>	<i>D. induta</i> , <i>D. purpurascens</i>	
2 complete transverse rings with dense hairs between	<i>D. linkii</i> , <i>D. carphoides</i>	<i>D. geniculata</i> , <i>D. richardsonii</i>	<i>D. linkii</i> var. <i>fulva</i>	
Very hairy (no definite transverse rings).			<i>D. pallida</i> , <i>D. bipartita</i>	

so far studied. The wide variation in *D. caespitosa* agrees with the morphological variability of this species and may be explained by the presence of various races among the plants.

There is a marked positive correlation between chromosome number and length of stomata (Fig. 1). The exceptions are few. *D. linkii* var. *fulva* and *D. bipartita*, each with 72 chromosomes, have markedly shorter stomata than other 72-chromosome species. *D. nudiflora* ( $2n = 24$ ) has stomata slightly longer than the shortest stomata found in the  $2n = 48$  chromosome plants. However, the most conspicuous deviation from the correlation was found in *D. frigida*, which grows in the alpine region of Australia and has  $2n = 42$  chromosomes. The stomata were found placed deeply in the grooves and are extremely small, measuring only  $26.6\mu$ .

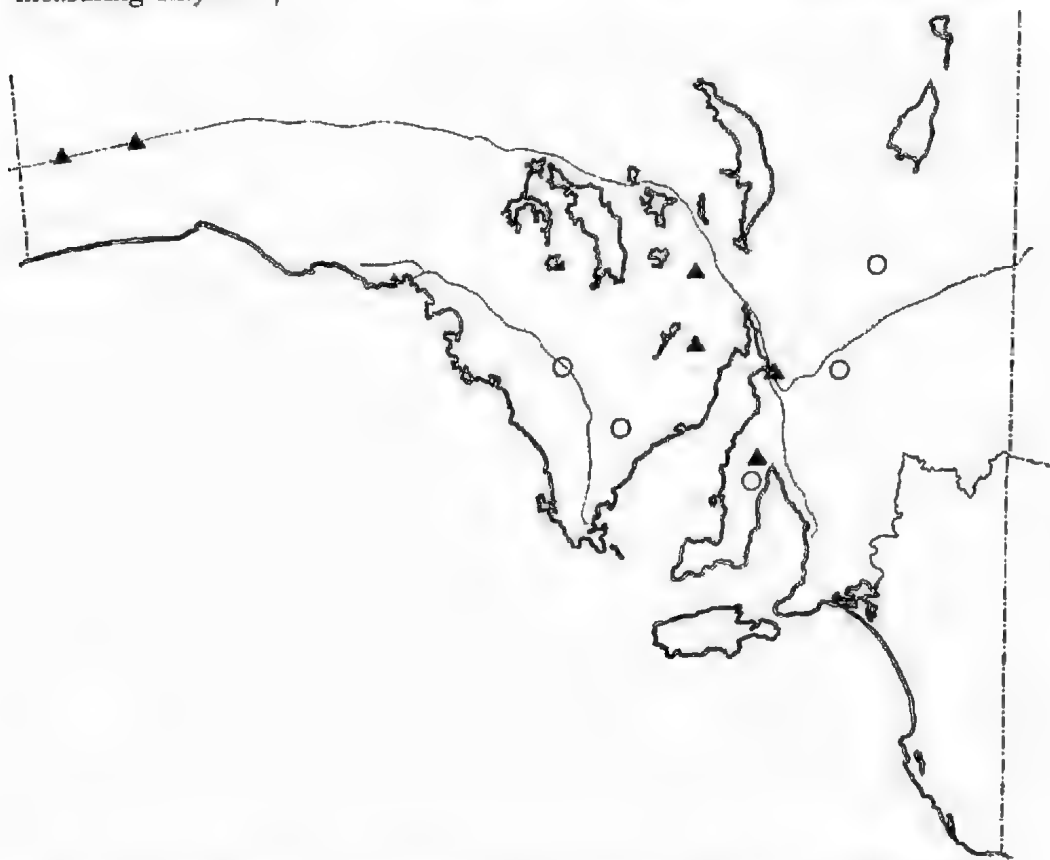


Fig. 3.—Distribution of 24-chromosome *D. caespitosa*. Reference; hollow circles — the chromosome number of collected plants counted; black triangles = only length of stomata on herbarium specimens measured.

### 3. Interspecific polyploidy and morphological characters

The principal character used in the identification of species of *Danthonia* is the abundance and arrangement of the hairs on the lemma. Accordingly, an examination has been made of the correlation between the hairiness of the lemma and level of polyploidy (Table 3).

It is apparent that increasing levels of polyploidy are associated with increased hairiness of the lemma. In some groups of species the relationship is

particularly strong, e.g. all species with only a lower ring of hairs have 24 chromosomes. On the other hand three species show disconformity from the general pattern, namely *D. linkii*, *D. carphoides* and *D. procera*.

#### 4. *Intraspecific polyploidy in Danthonia caespitosa*

The taxonomic species *D. caespitosa* at present includes a complex of forms distributed over southern Australia (Fig. 2). Collections from southern States have been grown, and from these a number of distinct forms have been separated (E. L. Robertson, private communication). Of the 62 plants examined cytologically, 51 had 48 chromosomes, 5 had 24 chromosomes, and 6 had 72 chromosomes.

The 24-chromosome group represents a morphologically distinguishable form, designated "form 6" by E. L. Robertson. As shown in the Fig. 3, this variant has been collected only from the drier areas of South Australia.

The contrast between a floret of this form and a 48-chromosome type is shown in Fig. 4.

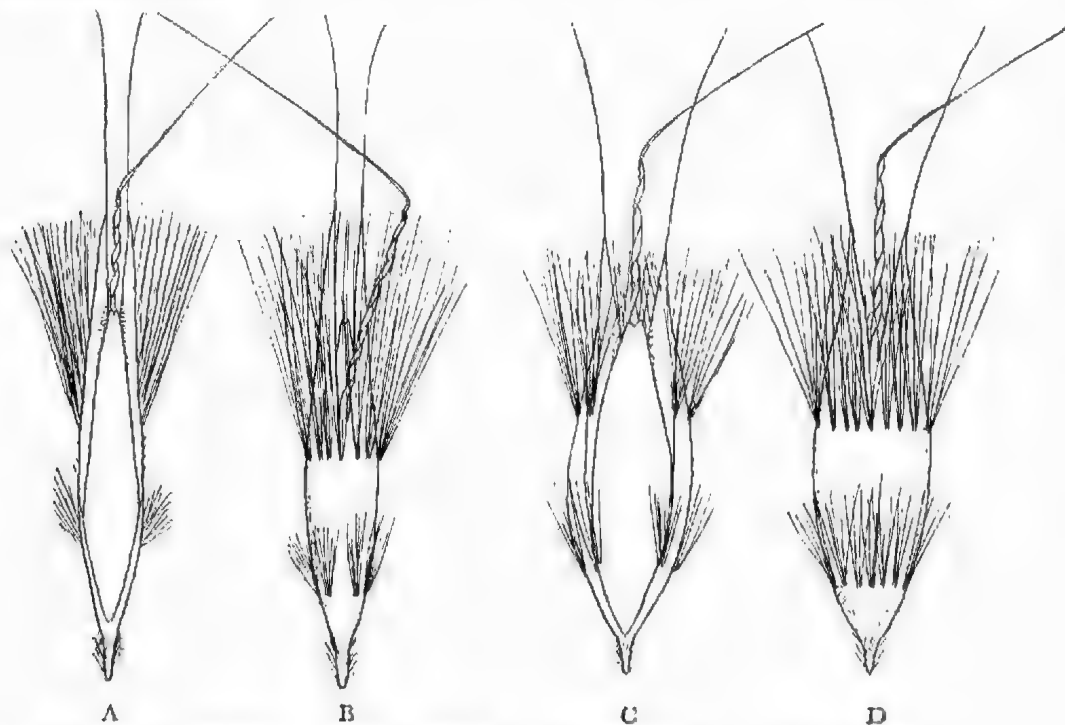


Fig. 4.—*D. caespitosa*. A, B—flowers of the 24-chromosome plant (A ventral, B dorsal view); C, D—flowers of the 48-chromosome plant (C ventral, D dorsal view).

Two 72-chromosome forms are very distinct from each other, but only one of them is distinctly different from the 48-chromosome group. The former has been found only in the Verdun-Ambleside area of the Adelaide Hills and possibly represents a distinct variety or species. It has robust, tall stems (2-3 feet in height) with glaucous-green foliage, entirely devoid of hairs except for the short ligule.

The other form representing one collection from Ungarra, Eyre Peninsula, has short, setaceous, pubescent foliage, with very short basal sheaths, and very



slender stems, and is not readily distinguishable from some of the 48-chromosome material.

All of the other specimens of *D. caespitosa* examined had 48 chromosomes and were of very diverse morphology.

## DISCUSSION

### 1. Polyploidy in the genus *Danthonia*

Since the levels of polyploidy in the genus *Danthonia* in various parts of the world are recorded as  $2n = 12, 24, 36, 48, 72, 96$  and  $120$ , it is clear that 6 is the basic number of most *Danthonia* species. The only species having  $2n = 96$  or  $120$  chromosomes have been found in Australia, but no Australian species is yet reported with  $2n = 12$  or  $36$ .

Calder (1937) postulates a basic number of 7 for New Zealand species with  $2n = 42$ . *D. frigida* is the only 42-chromosome species so far recorded in Australia.

In view of *D. frigida*'s affinity with some New Zealand species (Vickery, 1956) which also have 42 chromosomes, and the fact that only bivalents are formed at meiosis, 7 would appear to be a more logical basic number for this species.

The counts here recorded are in agreement with the previous counts made by other workers, except in three instances: *D. pilosa*, *D. semiannularis* and *D. bipartita*.

The different chromosome number recorded for *D. pilosa* by Calder (1937) from that found by Stebbins (Myers, 1947) and by the author may have resulted from a wrong identification of the material. Chromosome counts were made on *D. pilosa* and *D. semiannularis* sent by Calder from New Zealand. *D. pilosa* had the same number as found in Australian *D. pilosa*, i.e.  $2n = 24$ . One of the two plants received as *D. semiannularis* had  $2n = 24$  chromosomes, the other was identified at the Waite Institute as *D. caespitosa*. Calder has advised that botanists in New Zealand do not recognise *D. caespitosa* as growing in that country, and the 48 chromosome *D. caespitosa* had been identified as a form of *D. semiannularis*.

If each identification is correct the difference in the chromosome number of *D. bipartita* were De Wet (1954) found  $2n = 48$  chromosomes and the author  $2n = 72$  (derived from 36 bivalents in diakinesis and counted in root tips) may indicate that this species had developed intraspecific polyploidy. *D. bipartita* grows only in remote arid areas of inland Australia, and as mentioned above, is difficult to germinate and grow. Brock (unpublished) has recently counted  $2n = 120$  chromosomes in *D. induta* in material sent to him from the Waite Institute, but all material of *D. induta* examined here has shown  $2n = 72$ .

### 2. Chromosome numbers and length of stomata

Apart from the high correlation of chromosome number and stomatal length, and the aberrant species already noted, the principal point of interest is that *D. procera* with  $2n = 96$  chromosomes has shorter stomata than any of the  $2n = 72$  chromosome species. Though here based on a single species, this phenomenon has already been reported in other instances. Yamamoto (1938) observed that a hexaploid *Rumex acetosa* had smaller stomata than a pentaploid plant. Love (1944) noticed in his studies in *Rumex acetosella* that "from the hexaploid to the octoploid state, however, a diminution in the length of stomata is calculated". Tischler (1954) mentions (p. 230) the measurements of Duffield, who found that a hexaploid *Acer rubrum* has longer stomata than an octoploid plant of that species. Apparently there is a limit beyond which the length of stomata

ceases to increase with further increase in number of chromosomes, and this may also be the case in *Danthonia*.

### 3. Intraspecific polyploidy

(a) Turning to intraspecific polyploidy, it has been shown that the levels of ploidy in *D. caespitosa* are not wholly satisfactorily related to morphological characters. The 24-chromosome form appears to be reasonably well-differentiated and to have a limited distribution (Fig. 2). On the other hand, the 72-chromosome material includes two very distinct growth forms, though each has to date been recorded within a very limited area.

Present evidence does not elucidate the origin of the 72-chromosome race. However, its collection from the vicinity of both the 24- and 48-chromosome types in South Australia would support the hypothesis of it being a hybrid between these races.

Within the 48-chromosome material, which includes most of the material collected, there is a considerable diversity of morphological characters. Roth Nampfeldt (1938) and Love (1951) express the view that if more than one chromosome number is recognized in a taxonomic species, the species should be re-examined taxonomically with a view to its subdivision, even though differences in morphological characters prove to be small. In *D. caespitosa*, as now recognized by botanists, there is clear evidence for subdivision of the species based on chromosome numbers, and less sharply on morphological characters. The limited amount of material examined suggests that in South Australia some chromosome races may be geographically delimited in that the 24-chromosome type appears to occur only in the drier areas of the southern part of the State. Collections could profitably be made from the eastern edge of the distribution area of the 48-chromosome type in Western Australia and in western New South Wales to determine the generality of this situation.

(b) *D. longifolia*. In this species two chromosome numbers have been recorded, viz.:

(i) Chromosome number  $2n = 24$ , the length of stomata about  $28\mu$ .

(ii) Chromosome number  $2n = 48$ , the length of stomata about  $41\mu$ .

As one one plant of *D. longifolia*  $2n = 48$  and two plants  $2n = 24$  were collected, no comment can be made concerning the existence or distribution of chromosome races based on different chromosome numbers. No morphological differentiation among the three collected plants could be observed.

The regular pairing of the chromosomes and absence of multivalents at meiosis would suggest allopolyploidy. As the species of the genus *Danthonia* are recorded as being mostly autogamous, the small degree of outcrossing which must have occurred would result in rapid stabilization of new chromosome races.

### 4. Interspecific relationships

Vickery (1956) used the characteristics of the lemma as the morphological feature most likely to show the affinities of the various species within the genus *Danthonia*. Four series of species were postulated in this way.

The first consisted of a single species *D. bipartita* which was relatively isolated both in habit and floral character. Cytologically, this species is unique in that its chromosome morphology and behaviour at meiosis differs from that of all other species which tend to be rather uniform.

The second series was characterized by the scattered distribution of hairs on the body of the lemma. The chromosome numbers of these species were 24, 48 and 72. Vickery (1956) felt that the affinities of *D. frigida* appeared to be with a group of New Zealand species represented by *D. cunninghamii*, *D. raoullii* and *D. flavescens* rather than with this series. The cytological evidence

supports this view as both *D. frigida* and these New Zealand species are the only 42-chromosome species so far identified in the two countries.

The third series is centred on *D. caespitosa* and its extreme taxonomic diversity has not been clarified by a cytological study, as species with chromosome numbers of 21, 48, 72 and 96 have been identified in this group, quite apart from the complexity of *D. caespitosa* itself.

The final series have hairs of the lemma represented only by isolated marginal and dorsal tufts. All species of this series have 24 chromosomes.

A more extensive ecological and cytological investigation will be necessary to clarify the complex of inter- and intraspecific polyploidy but a definite pattern of relationships within the Genus is becoming obvious from the cytological and morphological evidence presented.

### ACKNOWLEDGMENTS

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# THE CHEMICAL COMPONENTS OF THE TEST OF AN AUSTRALIAN LAC INSECT AUSTROTACHARDIA ACACIAE (MASKELL)

BY *HARRY F. LOWER*

## Summary

The test of *A. acaciae* consists of chitin, protein, a dye, a wax, and a complex of lacs and lac-like substances. Of the latter, which constitute more than half the dry weight of the test, none could be identified as shellac. The dye and wax are also chemically distinct from those described from other insects.

# THE CHEMICAL COMPONENTS OF THE TEST OF AN AUSTRALIAN LAC INSECT *AUSTROTACHARDIA ACACIAE* (Maskell)

(Homoptera : Lacciferidae)

by HARRY F. LOWER\*

[Read 11 September 1958]

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## INTRODUCTION

Among the Homoptera, certain groups within the super-family, Coccoidea, are characterized by their secretion of large quantities of various waxes, or resinous materials, or both, which they incorporate into their tests or "scales". This mode of forming a protective covering for the body is most highly developed in the Lacciferidae or "lac insects" of which *Laccifer lacca* (Kerr), the Indian lac insect, is the best-known species.

There is an extensive literature dealing with its most important commercial product, shellac, and scattered references to insect waxes and dyes are to be found. The literature of the two latter has recently been reviewed by Warth (1956) and Fox (1953), respectively, while detailed accounts of the manufacture, physical and chemical constants, and industrial applications of shellac, such as those of Gardner (1937) and Parry (1925), are numerous. Apart from Fox (*op. cit.*) whose interest is in the chemistry of animal dyes generally, and Chamberlain (1923, 1925) who has provided the only complete taxonomic study of the family, the literature is entirely technological. Not only is this so, but its scope is limited to discussing three components of the test—shellac, wax and dye—and these of the one species *L. lacca*. Of the materials constituting the remainder of its test, or of any of the components of the tests of other lacciferids, nothing is known.

*Austrotachardia acaciae* (Maskell) is an endemic lac insect which is widely but irregularly distributed throughout the dry inland parts of Australia, where the environmental conditions admit of the growth of its host tree, *Acacia aneura* F. Muell. (mulga). The female secretes a thick, hard, brittle, dull orange-red test (Plate 1) which, in addition to the normal chitin-protein complex, contains over 60 per cent. of a variety of complex organic substances.

The material studied was collected from mulga trees on Yudnapinna Station, 50 miles N.W. of Port Augusta. Within the time at my disposal, practical difficulties made impossible the collection of material in quantity adequate for the complete examination of all substances present. Considerable distances often separate affected trees, rarely are parts of more than one or two boughs of any one tree infested, and in their colonies the insects are relatively dispersed. A further restriction of yield was imposed by the need for confining selection to

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dead insects, to obviate contamination of the sample with the body fats and fluids of living ones. Some extraneous matter was thereby unavoidably introduced in the form of desert dust, and the webbing and frass of spiders and larval scavengers. While the proportion of these was greatly reduced by subsequent treatment, it is almost certain that the greater part of the inorganic matter found was of external origin. Somewhat less than 50 g. of crude material were collected from which about 35 g. of sample were prepared.

### EXPERIMENTAL

(To obviate repetition throughout the paper attention is drawn to the following:

1. All drying was done to constant weight at 103° C.
2. "Ethanol" means absolute ethanol unless otherwise specified.
3. The substantive, *laccoid*, has been coined for substances which, while exhibiting many of the properties of the lacs, show by their mode of formation that they have much in common with fatty acids.)

The crude material was dried and the resulting cake, after breaking, was ground and as much as possible passed through a sieve of mesh diameter 0.246 mm. This eliminated webbing, and wood and leaf debris. The resulting powder was vigorously stirred with water in a tall cylinder and allowed to stand until the denser fraction had settled. The floating matter was then skimmed off, dried, and re-ground. This was the sample with which all work was done. Microscopic examination of the sludge showed it to consist almost entirely of silt.

Three 10 g. portions of the sample were individually Soxhlet-extracted with ether for 30 hr. The extracts were united, the ether distilled off, and the residue collected (*Extract A*).

The residues in the thimbles were then further extracted with ethanol for 40 hr. The extracts were united and evaporated to dryness (*Extract B*).

The residues in the thimbles, after drying, were digested under reflux for 10 hr. with boiling 5 per cent. hydrochloric acid, filtered under pressure, and washed with hot water until free from acid. Filtrate and washings were evaporated to dryness (*Extract C*).

The residue was digested under reflux for 6 hr. with 200 ml. of 0.1 molar boiling sodium carbonate solution. The mixture was filtered under pressure and the residue washed with hot water until the washings were free from carbonate. Washings and filtrate were evaporated to dryness (*Extract D*).

The residue was dried and weighed. It was then ashed, and the ash weighed.

The ash was boiled in three changes of *aqua regia*, each for 15 min. After each boiling, the insoluble matter was allowed to settle and the liquid decanted. The three extracts were united and evaporated to dryness (*Extract E*).

The residue remaining after treatment with *aqua regia* was heated to redness for 5 min., cooled and weighed.

### EXTRACT A (Ether-soluble)

Extract A was a soft, deep orange-brown solid. It was boiled under reflux for 12 hr. with 200 ml. of a proprietary wax solvent of high efficiency (see note at end). After cooling, the clear yellow solution was decanted and the residue boiled with three successive 50 ml. portions of the same solvent, each for 6 hr. The final extract was colourless and a drop of it evaporated without residue. The extracts were united and the solvent distilled off. The wax, after solidification, was twice recrystallized from a hot mixture of equal parts of chloroform and ethanol (charcoal).

After extraction of the wax, the residue was finely ground, well stirred with cold chloroform and filtered. The filtrate was evaporated, dissolved in ethanol, activated charcoal was added, and the mixture filtered. Evaporation of the solution gave a pure lac (Lac I).

The residue remaining after treatment with chloroform was dried, dissolved in 10 ml. of ethanol and sufficient N/10 ethanolic potassium hydroxide solution added to convert the original dye present into a potassium compound (insoluble in ethanol). The mixture was filtered and the potassium dye washed with hot ethanol until free from lac and alkali. The potassium dye was then dried, dissolved in 10 ml. of water and a slight excess of N/10 hydrochloric acid added to re-form the original dye which precipitated. The dye was extracted with ether, the solution washed twice with water, and the ether evaporated. The dye was twice recrystallized from hot chloroform.

### THE WAX

The wax is soft and pale yellow in colour. Its melting point is  $60.2^{\circ}\text{C}$ . It has an acid value of 95, a saponification value of 235, an ester value of 140, and an iodine number (Hühl) of 32.3. Approximately 6 per cent. of it is unsaponifiable. This fraction consists of a hard, faintly coloured, wax-like material of melting point  $70.4^{\circ}\text{C}$ . Lack of adequate material made further investigation of the wax impracticable.

### LAC I

Lac I is a dark, reddish-black, very hard lac which is brittle and breaks with a conchoidal fracture. It is very soluble in ethanol, chloroform or ether, but is insoluble in water, acetone or liquid hydrocarbons.

It has an acid value of 145, a saponification value of 302 and an ester value of 157. About 3 per cent. of it is unsaponifiable and consists of a hard, cream-coloured, wax-like solid melting at  $83.1^{\circ}\text{C}$ .

After removal of the unsaponifiable fraction, the solution was acidified and again extracted with ether. On evaporation of this extract, the lac acids remained as a soft, brownish-white, sticky mass comprising 55.6 per cent. of the weight of lac used. They were recrystallized several times from acetone (charcoal) and formed thin colourless plates having a melting point of  $55.5^{\circ}\text{C}$ .

### THE DYE

The dye is apparently present as the dye acid. It is insoluble in water or acids, irrespective of temperature. Hot concentrated sulphuric acid chars it; hot concentrated nitric acid vigorously oxidizes it. It is readily soluble in ether, ethanol of any concentration higher than 60 per cent., and somewhat less so in hot chloroform. On cooling its solution in the latter, the dye separates as glittering scarlet rhombic crystals. Depending on concentration, the colour of its solutions varies from dark blood red to yellow. Its absorption spectrum in ethanolic solution is shown in Fig. 1.

On addition of sufficient ethanolic alkali to solutions of the original dye, a compound of dye and alkali precipitates. This is apparently insoluble in all liquids except water in which it is highly soluble. The colour of the solution, depending on concentration, varies from blackish violet to pale violet. Addition of ethanol to the solution precipitates the dye compound as a black, microcrystalline solid; addition of acids precipitates the original dye. From the almost black saturated aqueous solution, the potassium compound crystallizes as black, glittering prismatic needles having a violet reflexion. Its absorption spectrum in aqueous solution is shown in Fig. 2.



Over the range pH 6.9 to 8.5, its colour changes from orange, through red, to violet. The colour is red at about pH 7.8 to 7.9.

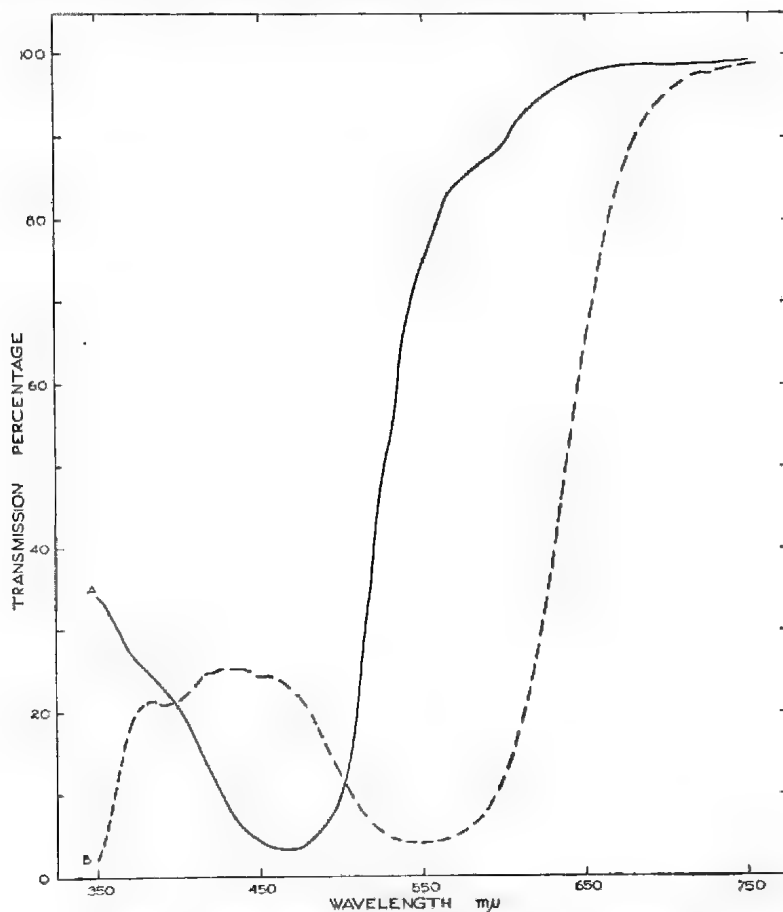


Fig. 1.—Absorption spectra of dye of *A. acaciae*.

A. Original dye in ethanolic solution. Concentration: 0.03125 g./litre.

B. Potassium compound in aqueous solution. Concentration: 0.03125 g./litre.

#### EXTRACT B (Ethanol-soluble)

The solid dark brown material was finely ground, digested under reflux for 10 hr. with boiling ethanol, and the residue twice digested (each for 5 hr.) with fresh boiling ethanol. The three extracts were united, activated charcoal was added, the mixture filtered and the filtrate evaporated to dryness (Lac II).

When ethanolic extraction was complete, about 54 per cent. of the original extract remained as a flocculent material closely resembling precipitated copper ferrocyanide in appearance. This was dried and weighed (Gel lac).

#### LAC II

Lac II is a hard, brittle, bright orange lac, very similar in appearance to orange shellac. It melts between 140° C. and 142° C. Very soluble in ethanol and somewhat less so in methanol, it is insoluble in any other of the commonly

used organic solvents. It has an acid value of 95, a saponification value of 248, and an ester value of 151. The unsaponifiable fraction comprised 2.4 per cent. and consisted of a hard, yellowish, wax-like material melting at  $96.1^{\circ}\text{C}$ .

After removal of the unsaponifiable material by ether extraction, the mixture was acidified and the resulting lac acid extracted with ether; the ether extract was evaporated and the residue thrice recrystallized from hot acetone (charcoal) forming golden-yellow, glittering scales whose melting point was  $107.3^{\circ}\text{C}$ . On cooling the melted material, it solidified as a hard orange-yellow, transparent, resin-like mass lacking the physical properties associated with fatty acids generally. It is only slightly soluble in boiling ethanol, but is very soluble in cold ether, chloroform, carbon disulphide or boiling acetone. From its solution in the latter most of it separates on cooling.

#### THE GEL LAC

This consisted of a brittle, black, vesicular mass which boiling ethanol restored to the original flocculent condition. It was insoluble in any of the 43 organic solvents and solvent mixtures tested.

When the solid is heated, it does not melt but decomposes into a spongy, carbonaceous mass evolving a dark dense vapour which condenses as dark red, oil-like droplets soluble in ethanol forming a reddish solution.

It was boiled with N/2 ethanolic potassium hydroxide and formed a deep, brownish-black, opaque solution which passed unchanged through filter paper. Ether extracted nothing from this solution. It was then diluted with water, placed in a separating funnel, sufficient hydrochloric acid was added to make the mixture acid, and the whole was well shaken with ether. On standing, three layers formed. The lowest consisted of an aqueous-ethanolic solution of potassium chloride coloured yellow by a trace of impurity. The middle layer was oily and black, and above this floated the orange ether layer. After running off the bottom layer, the two upper ones were well washed several times with water, allowed to stand, and then separated.

The black material was dried, dissolved in ethanol (charcoal), filtered, and again evaporated giving a black lac-like material (Laccoid I).

The ether extract was evaporated, and the residue recrystallized several times from hot acetone (charcoal) (Gel lac acid).

#### LACCOID I

This is a highly polished, pitch-like material, very hard and brittle, readily soluble in ethanol but insoluble in other solvents. On heating, it melts quietly at about  $127^{\circ}\text{C}$ . Boiling it with either aqueous or ethanolic alkali re-saponifies it forming a deep reddish-brown solution from which it can again be set free by acidification. Prolonged boiling with fat or wax solvents dissolves nothing from it. Its nitrogen content is 0.45 per cent.

#### THE GEL LAC ACID

From its solution in hot acetone, the acid separates as a deep orange, apparently amorphous, material. On heating, it softens and finally melts at about  $109^{\circ}\text{C}$ . On re-solidifying, it forms a transparent, glassy, deep orange-red, brittle solid. It dissolves readily in fat solvents and in hot acetone, but is insoluble in boiling ethanol. Aqueous or ethanolic solutions of alkalis readily re-saponify it.

#### EXTRACT C (Hot HCl Extract)

As first obtained, this was an orange-brown solution which, during evaporation, underwent chemical change so that the dark brown amorphous residue

could not be re-dissolved in hydrochloric acid, nor was it soluble in any other solvent tested. After boiling with ethanol, and evaporating the yellow solution, a trace of a dark brown, mucilaginous substance remained. This was dissolved in a little hot water, and the solution after decolorizing with charcoal and filtering, gave a positive result with Mölisch's reagent, but none with Fehling's solution. Since less than 0.1 g. of material was available, further tests could not be performed.

The original residue contained 8.1 per cent. of nitrogen and probably consisted largely of "humins" formed by decomposition of amino-acids resulting from hydrolysis of the proteins of the test by the hydrochloric acid used for the extraction.

#### EXTRACT D (Sodium Carbonate Digest)

The sodium carbonate extract, on evaporation, left an almost black residue. After boiling with water, a small quantity of black insoluble matter was filtered off. Ether extracted practically nothing from the filtrate which was then acidified with hydrochloric acid. A dense precipitate formed. When the mixture was warmed, this coagulated to a yellowish-brown rubber-like mass. The mixture was then evaporated to dryness and the residue digested three times (each for 5 hr.) under reflux with boiling ether. The extracts were united and the ether distilled off, leaving a lac acid.

After expelling remaining ether, the residue was ground, dissolved in ethanol (charcoal), filtered and evaporated (Laccoid II).

#### THE LAC ACID

The crude lac acid was a soft, orange-coloured, wax-like material. It was several times recrystallized from hot acetone (charcoal) and finally obtained as almost colourless plates (melting point  $68.2^{\circ}\text{C.}$ ). When the acid was melted and allowed to solidify it formed a soft, cream-coloured, waxy material.

#### LACCOID II

This was a very hard, black, lac-like material practically insoluble in all liquids except ethanol and methanol. It is extremely soluble in the former. Boiling with aqueous or ethanolic alkalis quickly brings about its saponification. From the solution it can be recovered by acidification. On heating, the solid does not melt but swells, bubbles, and evolves dense fumes which on condensing form an oil-like stain easily soluble in liquid hydrocarbons. Its nitrogen content is 2.3 per cent.

#### RESIDUE REMAINING AFTER SODIUM CARBONATE EXTRACTION

The residue left after sodium carbonate extraction, when dried, was a white material resembling bleached paper-pulp. It was weighed, ashed, and the ash then weighed. The loss in weight was assumed to be chitin.

The ash, after treatment with *aqua regia* (presumed to be silica) was weighed.

After weighing, the dry *aqua regia* extract was dissolved in dilute hydrochloric acid and the solution tested qualitatively for inorganic ions. The following were identified:  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$ ,  $\text{Fe}^{++}$ ,  $\text{PO}_4^{--}$ , and  $\text{SO}_4^{--}$ .

#### DISCUSSION

The major components of the test of *A. neneiae* are shown in Table I. Since the dye, wax, and lacs I and II were separated in a relatively pure state, their proportions are reasonably correct. The "gel lac" and the acid and sodium carbonate extracts are mixtures of at least two and probably more substances. Evidence obtained during the investigation proved that had more material been

available, the diversity of substances identified would have been much greater. Frequently, traces only of certain organic compounds were isolated, the quantities of which were too small for anything other than a very general classification. The figures for silica and the inorganic ions are artificial; these materials are almost certainly of extraneous origin and form no intrinsic part of the test.

TABLE I.  
Principal constituents of the test of *A. acaciae*.

Component	Weight in grams	Percentage of weight of test
Dye	0.594	2.0
Wax	2.346	7.8
Lac I	3.935	13.1
Lac II	4.313	14.4
"Gel Lac"	5.027	16.7
"Humin"	4.050	13.5
Sodium carbonate extract	3.350	11.2
"Chitin"	4.038	13.5
Silica	0.984	3.3
Inorganic ions	0.101	0.3
Loss	1.262	4.2
	30.000	100.0

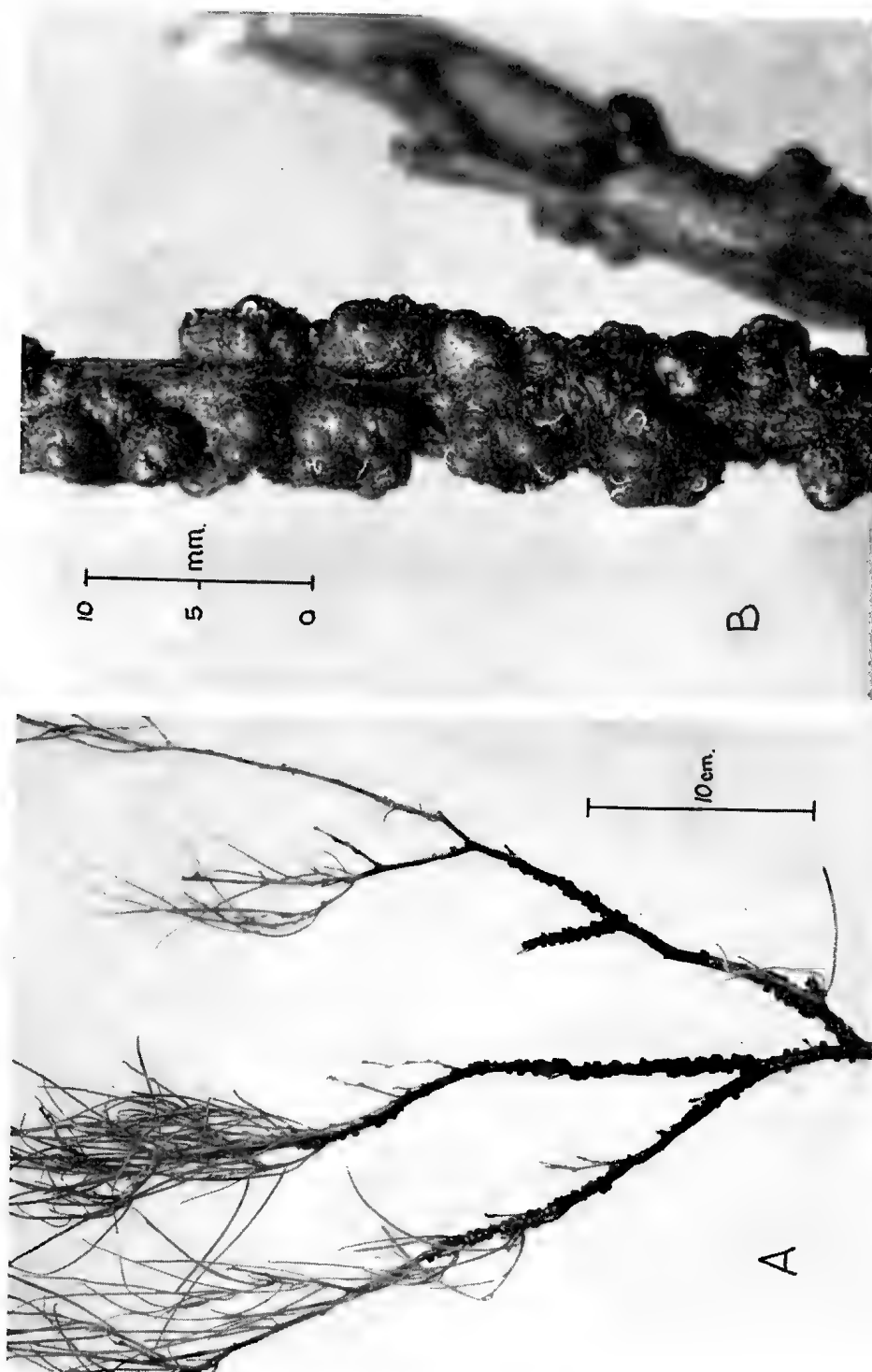
Since no corresponding study of any other lac insect has been published, little comparison with allied forms is possible. The wax and the dye are both chemically distinct from those of *Laccifer lacca* (see Warth, 1956; Fox, 1953), and the dye differs from any which has been described from other insects. Of the various members of the lac complex present, none is shellac as is shown by their solubilities, and acid, saponification, and ester values (see Gardner, 1937; Parry, 1925). The two laccoids separated are interesting compounds. In their general behaviour they resemble high melting point lacs, but their mode of chemical formation indicates a relationship to the lac acids. They are not present in the test as laccoids since their ready solubility in ethanol would result in their extraction earlier in the analysis.

As the name "lac insects" implies, production of lacs is characteristic of the Lacciferidae. In *A. acaciae* they comprise over half the dry weight of the test, but their biological significance in any species has never been explained, little is known of their mode of secretion, and nothing of their metabolism or function.

NOTE.—The proprietary wax solvent mentioned above is marketed by the Vacuum Oil Company as "Stanvac Hexane". It consists of 93-95 per cent. saturated hydrocarbons and 7-5 per cent. of aromatic hydrocarbons. The boiling point range (A.S.T.M.) is from 66° C. to 68.5° C.

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*Austrotachardia acaciae* (Maskell)

1. Distribution of insects on stem.

2. Part of A enlarged to show external appearance of individual insects.

# STRANDED SEA BEACHES AND ASSOCIATED SAND ACCUMULATIONS OF THE UPPER SOUTH-EAST.

BY R. C. SPRIGG

## Summary

Highly detailed geomorphic information concerning the distribution of sand dune systems in the upper south-east provinces of South Australia is provided. A large "stranded coast" embayment encloses Tintinara and Keith as part of the earliest Naracoorte beaches, and with it the deep Pleistocene shell deposits described by Tate (1898). This is the Tintinara "Bay". Suggestions are made for the northerly continuation of the Kanawinka fault or its en echelon associations from Naracoorte immediately east of Keith to the Marmon Jabuk Range. These fault escarpments did much to fashion marine and lake coasts at about the beginning of the Pleistocene Era. A rapid increase in quartz is found in modern beach sands north of Kingston towards the outlet of the Murray River. This is held to be of principal importance in the development of the leached silicious sand sheets in the upper south-east rather than simply podolization of high-lime beach sands. Wind directions remain dominantly E.-W. during the course of all high sea level phases of the Pleistocene (as evidenced by inland dune trends). The modern coastal dune structures, however, approximate N.E. in conformity with prevailing wind patterns requiring a four or five degree *southward* migration of the "Roaring Forty" prevailing westerly belt since the Pleistocene.

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### INTRODUCTION

Ground observations supported by widespread aerial reconnaissances by the writer since 1954 have provided much new information concerning the history of this region. A highly detailed map compiled by the writer from the latest aerial photography by the South Australian Lands Department goes far to elucidate this history.

The present paper is one of a series, arising from efforts to obtain more factual information on structural deformation of the larger sedimentary basins in South Australia, during Recent geological times. The dating of certain land movements in these basins are of particular interest in the search for commercial oil.

This present paper is designed to deal with coastal migrations of the late Cainozoic Era as they affect the upper south-east. In this respect it is supplementary to earlier papers by N. B. Tindale (1933), P. Hossfeld (1950), R. Sprigg (1950-2) and P. Du Mooy (1958). Of particular concern is the fate of the older "Naracoorte" and "Hynam" beaches, as they trend north-north-easterly from the Naracoorte vicinity beyond the immediate influence of the scarp-forming Kanawinka fault. These beaches were known generally to strike towards Tintinara where Tate (1898), Howchin (1929) and others had described a thick section of "Newer Pleistocene" shell beds extending from 38 feet above to 182 feet below modern sea-level.

Considerable land warping continued throughout the period of beach formation, and strong differences of opinions amongst geologists still remain to

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\* Geosurveys of Australia Ltd.



be resolved as to the effectiveness, and even the existence, and direction of these complicating movements.

### GEOLOGICAL BACKGROUND

Outcropping basement rocks in the south-east are all acid igneous types which Mawson (1913, 44, 45) has classified in three major groups. They include the reddish granite of the Murray Bridge type in which fluorite is a notable accessory, also the greyish porphyritic adamellites and granodiorites, and finally the quartz keratophyres considered to be effusive equivalents of the adamellites and granodiorites. They are considered to be comagmatic with similar intrusions in the eastern Mt. Lofty Ranges and southern Kangaroo Island to the north and west, and perhaps with those of Dergholm to the south-east in Victoria.

These granite rocks outcrop in isolated inliers, as knolls and "whalebacks" throughout the present region along the crest of the so-called Padthaway buried horst (Sprigg, 1952).

Permian glacials infill many glacial valleys in an ancient buried topography excavated in the foregoing terrain. Glacigene sands and clays and boulder beds are indicated in drilling, but these do not appear to outcrop in the area.

Mesozoic subgreywacke, coals, and shales are present to a thickness of 3,000 feet in Robe Bore, but are not recorded in the present area. Three samples between 1,400 and 2,630 feet in Robe Bore have been determined (Cookson and Dettmann, 1958) as of Lower Cretaceous age.

Older Tertiary sediments of Eocene age are principally paralic sediments with local lignite of the Knight and Buccleuch Groups (Ludbrook, 1957). They are overlain by normal marine limestones mostly of Upper Oligocene age.

Most of the present land surface is now blanketed by sands highly siliceous in the north, but more calcareous to the south where they form "aeolianite" dune rock. Travertinization is widespread where the calcareous element is stronger, and laterization or soil hard-pan formation is conspicuous in restricted areas.

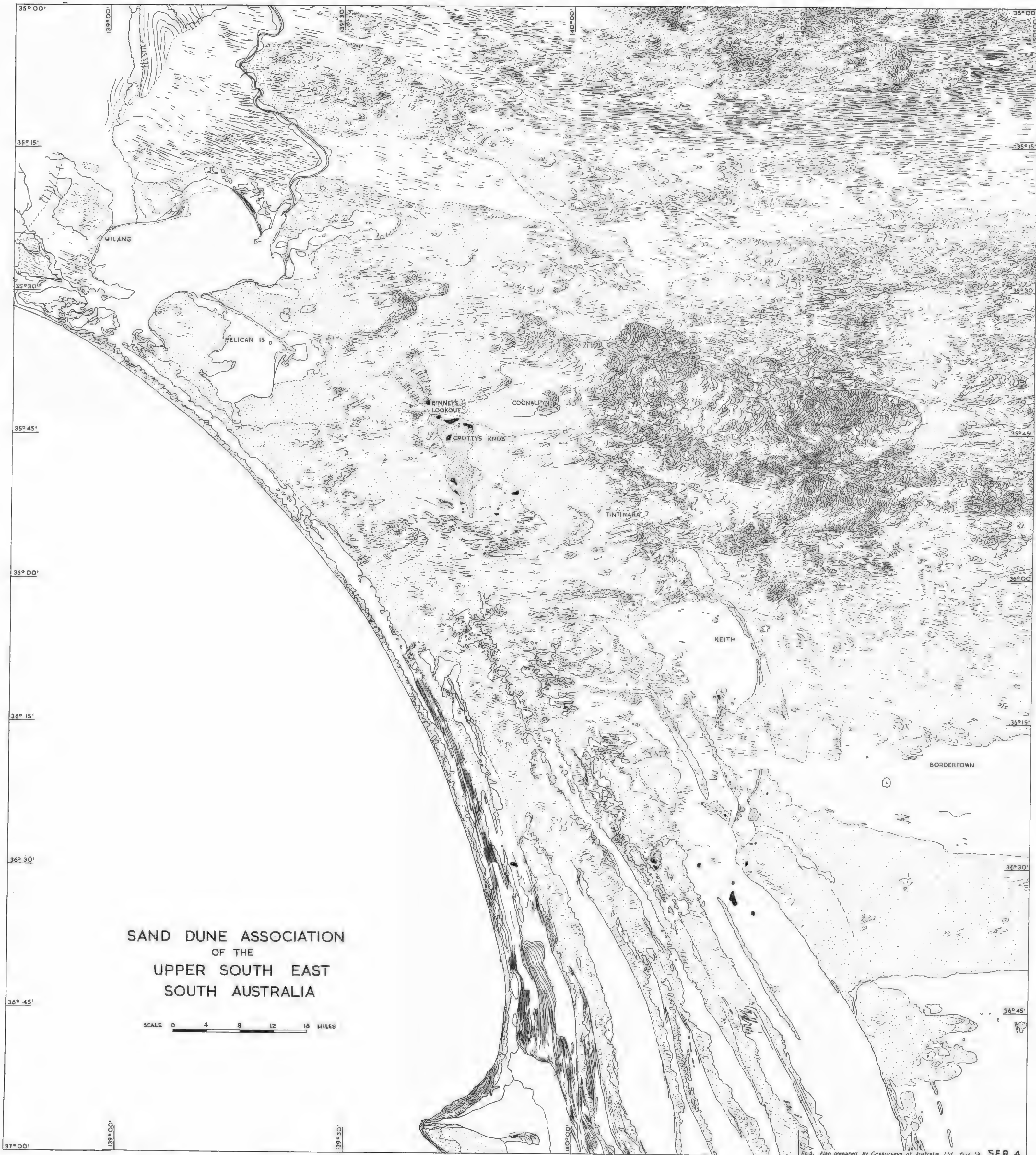
### THE (?) PLIO-PLEISTOCENE COASTS

There is no reliable indications as to the exact dating of coasts in this area. At about the end of the Pliocene the sea receded completely from the "Murrayian" Gulf of which the present area is part. This was accompanied by uplift of an ancient N.N.W.-S.S.E. ridge known as the Padthaway Horst (Sprigg, 1952). As Howchin (1929) had noted, the original mid-Tertiary Gulf became a great inland lake or series of lakes behind this general zone. The engrafted River Murray drained into it. The position of the sea coast during late Miocene to early Pliocene times is not known and may have retreated beyond the limits of the modern coast, but certainly appears to have retreated at least to the Padthaway Horst.

During Pliocene times the sea gained access to an elongate topographically negative zone close by the uprising Mt. Lofty Ranges, and massive oyster beds extended along the general course of the Murray valley in this region, as far north as Morgan.

To the south of Naracorte, there is a multiplicity of very obvious stranded sea beaches mostly of Pleistocene ages. These have been stranded in turn on an upwarping but gently seaward sloping plain (Fig. 2). Some complications have been noted (Sprigg, 1948, 1952; Hossfeld, 1950) by later inundation of the lower (younger) beaches.

The best developed of the higher (older) stranded beaches occur at Naracorte against the Kanawinka fault scarp, developed in mid-Tertiary polyzoal



SAND DUNE ASSOCIATION  
OF THE  
UPPER SOUTH EAST  
SOUTH AUSTRALIA

SCALE 0 4 8 12 16 MILES



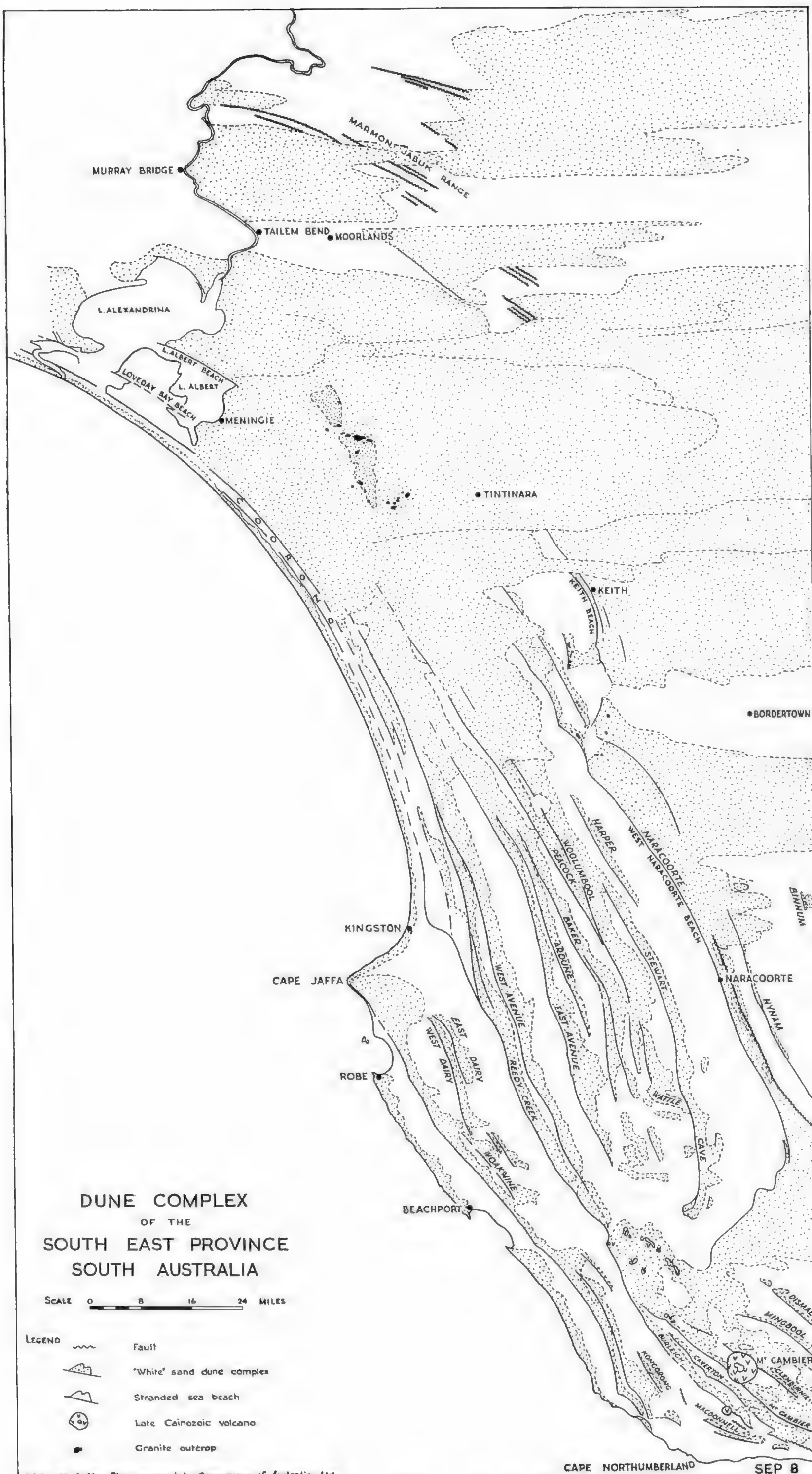


Fig. 2

limestones, and attaining more than 100 feet high. Remnant sub-parallel coastal dunes occur further inland at still higher levels marking the "Hynam" and "Binnum" coasts. The Naracoorte dune has been taken by Sprigg (1952) to be the earliest Pleistocene dune, and the Hynam and Binnum coasts on this assumption would be of Pliocene age.

Further to the south extensive oyster deposits occur inland from the Dismal Swamps on the "back" of the Mt. Gambier arch (Sprigg, 1948, 52), or Cape Banks axis (Hessfeld, 1950). These may or may not be time-equivalents of the Murray Valley deposits to the north. They appear to be co-extensive with the Plio-Pleistocene deposits of the Glenelg River at Heywood in south-western Victoria described by Singleton (1939) as spanning this "time" boundary. The western Naracoorte beach is contemporaneous with these oyster deposits and so a Plio-Pleistocene "boundary" age for this beach seems reasonable. The sea at this time lapped at the foot of the Kanawinka fault scarp.

The Naracoorte beach dune is compound. It consists of two major ridges separated a short distance (a few hundred yards) from the Kanawinka fault at Naracoorte, which also appears to have formed a (slightly older) coast.

To the north, the seaward facing aspect of the "west" Naracoorte component of this beach dune trends consistently N.N.W. with only gentle arching more to the N.W. to within 15 miles of Keith. Here there appear numerous complications. Granites outcrop boldly, and at least 3 or 4 coastal dunes appear east of the "Naracoorte" trend, variously arched into successive embayments controlled in part by protecting granite "headlands" (Fig. 3). The younger of these may be correlated with the west Naracoorte dune and this interpretation is preferred. The next east includes several granite eminences within its boundaries near the southern end. The Mount Monster dune, next to the east, may not have been a complete coast, but rather a string of granite islands "tied" by dune accumulations. Further east the compounded Keith dunes make a prominent coast forming the Tintinara "Bay" and backed by enormous east-blown siliceous sand sheets which rise relatively sharply from the dune fore-front level of 90-100 feet to 200 feet or more. It is not improbable that this dune skirts the northern continuation of the Kanawinka fault or a related en echelon fracture and escarpment.

The Keith "beach" can be traced north-eastward to opposite Tintinara (74 feet above sea level) beyond which it is lost beneath enormous sand blows originating from about the seaward granite "islands" of the Binneys Lookout and Mt. Boothby "archipelago". This and associated "blows" effectively obliterate all coastal dunes north of this latitude. South from Keith this Tintinara "Bay" swings seaward to link with the Naracoorte trend, but in doing so, also is "tied" to the Mt. Monster archipelago.

Of the younger (lower level) dunes west of the "Naracoorte" line, most of them lose their identity north of the latitude of Keith. Only the Peacock dune can be traced beyond this limit, with the exception of the immediate sub-coastal "Reedy Creek" beach and others of the "Courong" association.

In the region of the Murray Lakes to the north (Fig. 4) evidence of former coasts is difficult to elucidate. Enormous sand sheets and "blows", and lakes, effectively blanket most of the evidence. The northern shore of Lake Albert has a gently arched form and is backed by high sand dunes and is thought to represent an old sea stand, probably the Naracoorte coast. Further west, constrictions on Narrung Peninsula also suggest the trace of an ancient coast, possibly one of the "Avenue" beaches, from the south. This has been tentatively termed the Loveday Bay Beach.

The role of the Mt. Boothby and Binneys Lookout granite whalebacks in coastal configuration can only be surmised, although the protection must have

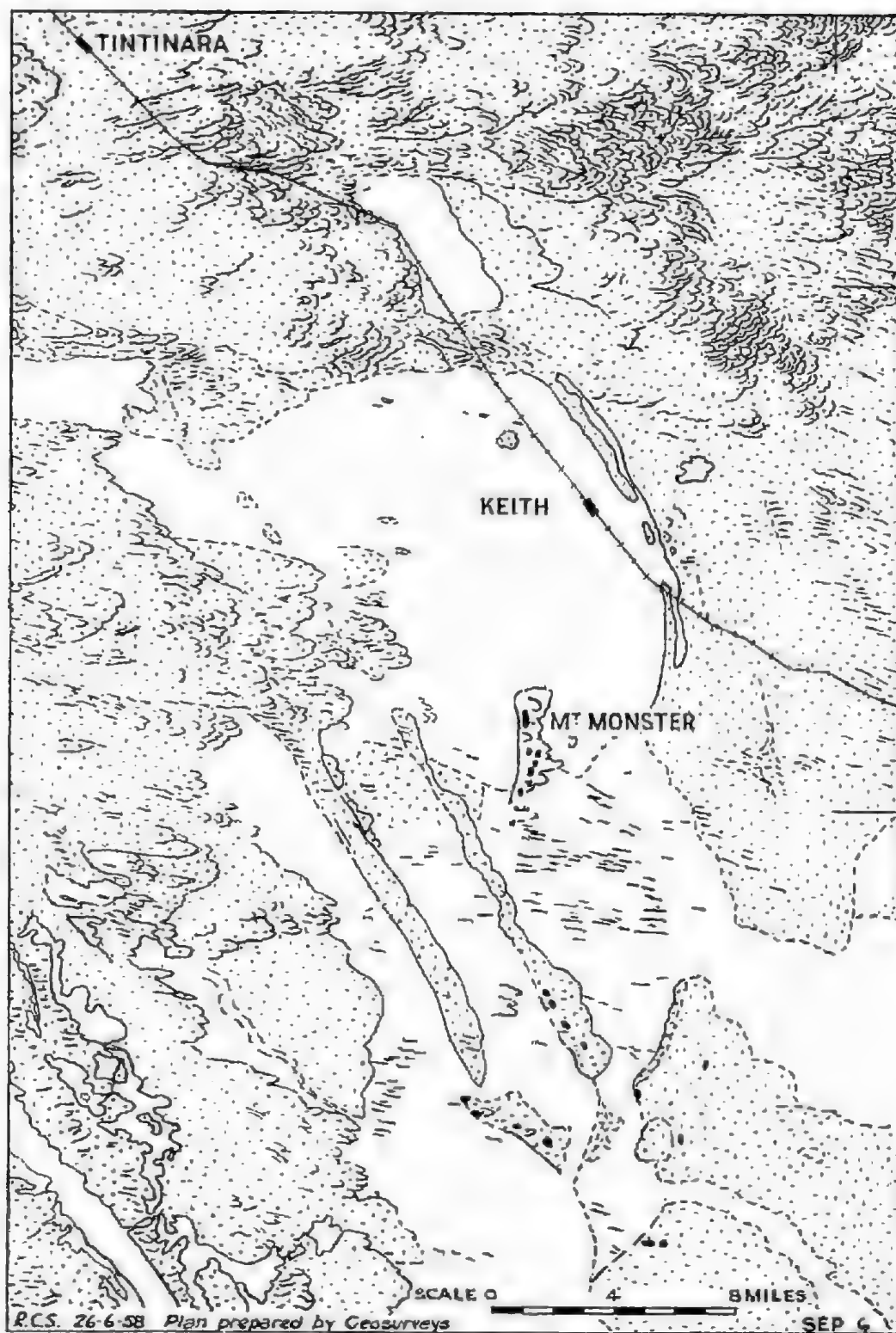


Fig. 3

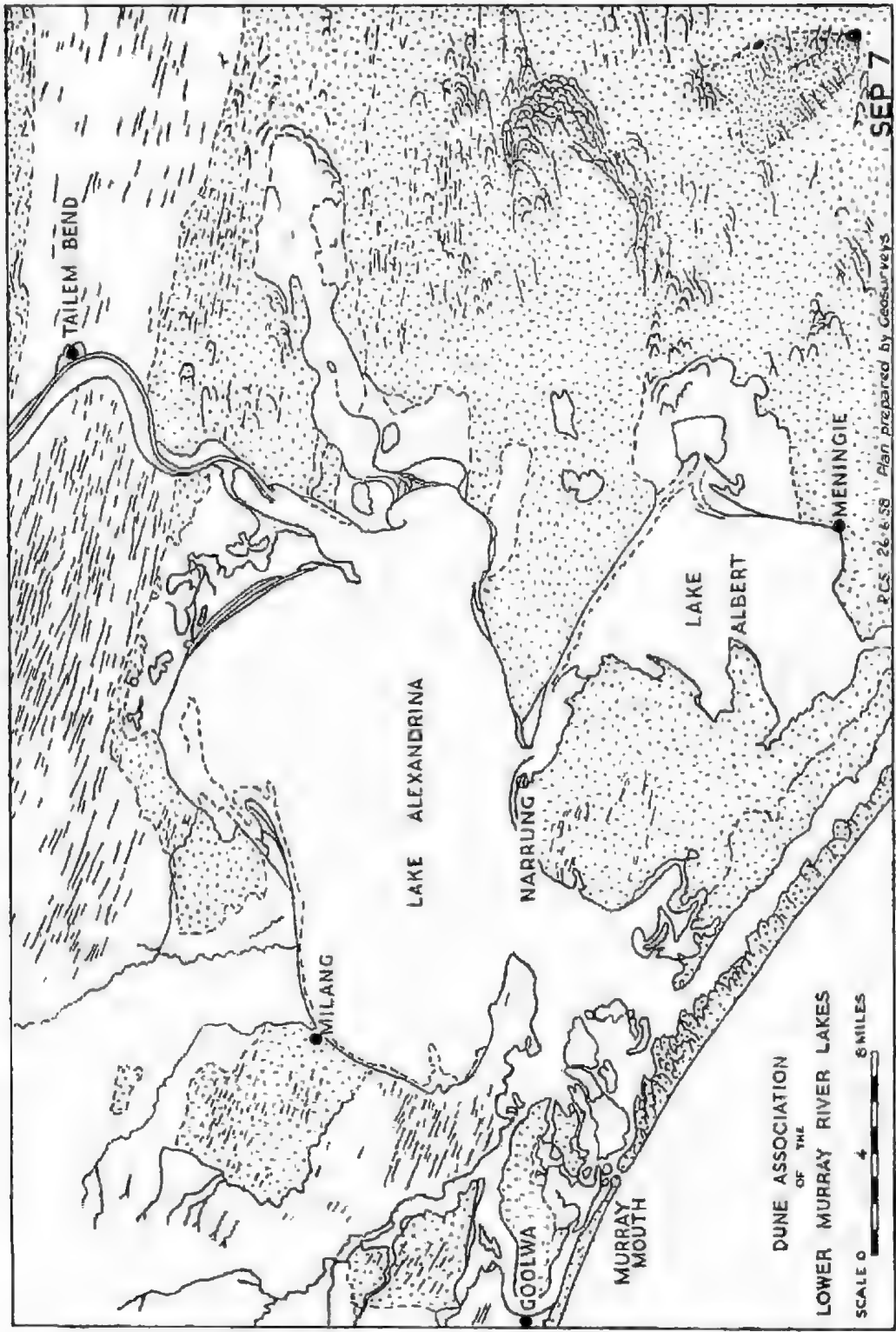


Fig. 4

had considerable influence on local coastal configuration. Presumably these granite knolls formed archipelagoes and tied-islands and finally headlands in successively younger stranded coasts. The outcrop undoubtedly facilitated inland sand drift, for the most massive "blows" surround these and extend for 200 miles inland directly eastwards.

## DISCUSSION.

### (a) *The Tintinara Marine Shell Deposits*

Appreciation of the form of the stranded "Tintinara Bay" and associated coasts throws new light on several previously puzzling features. Tate (1898) examined fossil shell assemblages from the Tintinara Railway Bore, and declared them to be New Pleistocene. He recorded that "the total thickness of New Pleistocene beds is 220 feet extending in depth from 38 feet above sea level to 182 feet below it. All the examined species as a result of comparison with authenticated specimens are, with three exceptions, living in our local seas."

Chapman (1916) following this evidence of deep shell beds extending well below modern sea level, suggested the possibility of a rift valley or an earth fold by which the sea was admitted. Some overdeepening seems certainly to have occurred, and may have marked an ancient erosional valley, or as Howchin and Tate suggested, a possible outlet of the Murray River.

The new view of the landward swing of the "East-Naracoorte" or older coasts, as herein described, accommodates the Tintinara shell deposits within the older Tintinara embayment. Tate's identification of "Newer" Pleistocene should be accepted cautiously in the absence of more precise determinations, but an older Pleistocene age would appear to be more in accordance with the facts.

### (b) *The Northward Continuation of the Kanawinka Fault*

Another problem concerns the northern extensions of the Kanawinka fault. This gently arcuate fault extends more than 100 miles from near Portland in Victoria, west of Casterton and through Naracoorte, to disappear into the Naracoorte stranded coastal dunes only a few miles north of the latter town.

Topographic data is sparse in this direction. Railway gradients between Tintinara (R.L. 62) and Keith (R.L. 101) are quite low (30 feet in 24 miles), whereas to the east, the rise across the "Keith Coast" is 40 feet in 8 miles. This could indicate the position of the projected Kanawinka fault extension or a en echelon partner, but is also attributable to sand accumulation. No granites outcrop west of this line.

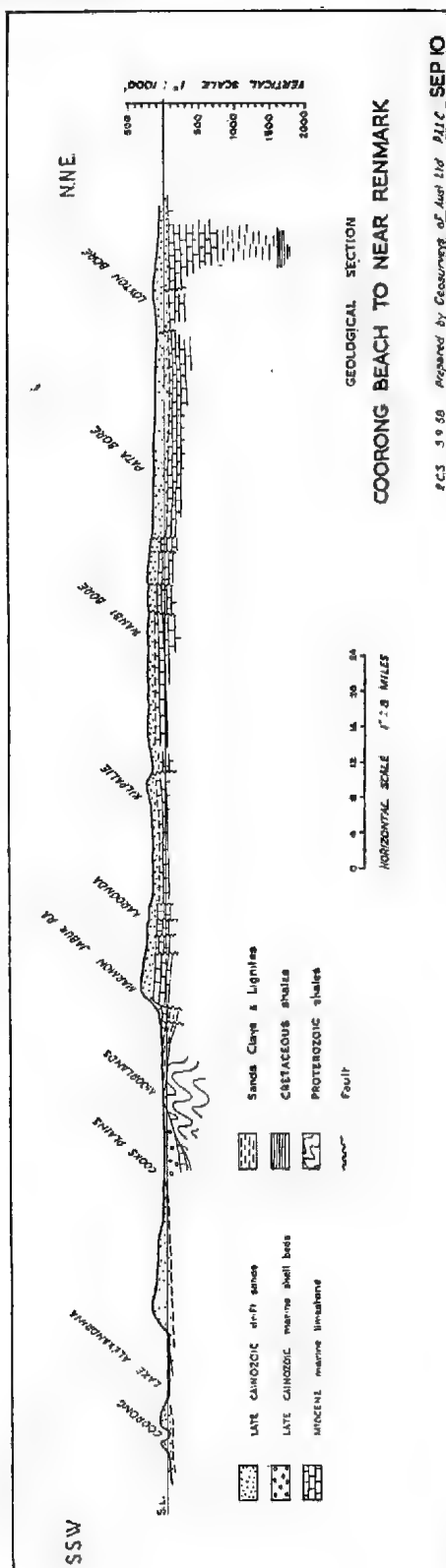
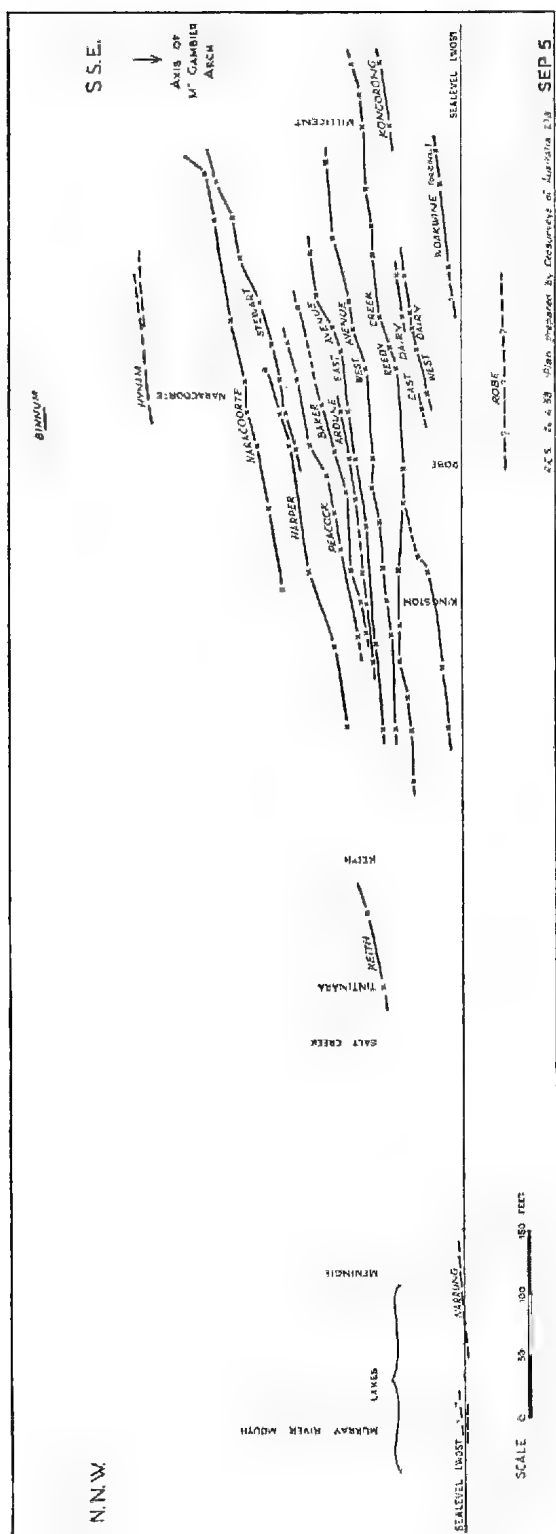
To the north-west, numerous faults all trending N.W., W.N.W. or N.N.W. continue the general zone of uplift, and certain of these mark the boundaries of the Marmon Jabuk Range. (See Figs. 2 and 6.) These relationships are being discussed more fully in a parallel paper.

### (c) *Landwarping Movements.*

Particular interest centres upon the extent of landwarping movements active throughout the Late Cainozoic Era, which is widely known in Australia as the "Kosciusko Epoch".

A graph (Fig. 5) has been prepared of stranded beach "forefront" levels, projected onto a sub-parallel plane taken along the general average trend of the beach system. It is appreciated that true strandline, or other "datum", may vary plus or minus 10 or 20 feet or more along these situations. In general, however, erosion and deposition along the fore-dune flats since the stranding of the respective beaches will have acted to reduce these elevational differences. For example, in the extreme south, on the axis of the transverse Mt. Gambier arch





(or upwarp) Tertiary rocks are extensively exposed by sediment stripping, whereas to the north the interdune flats are progressively more deeply swamped by later sediments. The graph, then, will tend to indicate rather a lesser amount of warping than has actually occurred.

The warping trends are quite obvious from the graph, indicating progressive upwarp about the Mt. Gambier (or Cape Banks) line, with greatest downwarp towards the foot of the (developing) Mt. Lofty Ranges. It is this type of downwarp towards the eastern edge of the Mt. Lofty Ranges and the eastern and northern margins of the Flinders Ranges which has exercised a major control on stream patterns in the Murray River and Lake Eyre basins. These patterns are notably asymmetrical with all trunk streams trending towards, and finally along, the base of the previously mentioned margins of these ranges. These are also the zones of South Australia's major lakes. The graph produced clearly supplies the controls for this situation.

(d) *The Origin of the Sands*

Enormous volumes of white or cream coloured sands in vast sheets extend for up to 150 miles from the present coast almost directly eastwards into Victoria (the "Big Desert" in the north, and "Little Desert" to the south). These are the leached siliceous sands described by Crocker (1946) and others. Crocker concluded the enormous volumes of sand to be "aeolian resorted leached A-horizons from the former calcareous dunes . . . the consolidation of the calcareous dunes by downward leaching of lime and re-deposition in a B-C horizon, has resulted in the formation of a residual siliceous A horizon. The stripping of this siliceous horizon by aeolian agencies during a subsequent arid period, and its re-sorting is considered to have led to the development of the large areas of siliceous sand in the lower south-east".

Obviously these processes have played some part in the development of the siliceous sand sheets of the upper south-east, and of some consolidated "aeolianite" dunes, but other more important factors have been overlooked.

Firstly, all coastal sands in the south-east are not dominantly calcareous. Crocker (1946), for example, has quoted 5.35 per cent. insoluble matter as the normal range of variation for "our Australian calcareous sands". Analyses of sands taken by Sprigg (1952) in the lower south-east certainly do indicate uniformly high lime content (65-95 per cent.) as suggested by Crocker (i.e. 5.35 per cent. insolubles). However, these samples were all taken from the vicinity of Kingston or south in a region notable for destruction of enormous shell populations on open ocean surf beaches which lack river outlets which would otherwise provide non-calcareous sedimentary material. Kingston, for example, is almost 90 miles from the Murray River mouth to the north, and 120 miles from the Glenelg River outlet to the south-east.

A series of sand samples taken at intervals along the Coorong Beach north from Kingston show a progressive increase in insoluble as follows:

10 ml. S.W. of Kingston	.. .. .	L.T.L.	11.7
10 ml. N. of Kingston	.. .. .	{ L.T.L.	28.8
		{ H.T.L.	22.0
20 ml. N. of Kingston	--- .. .	Dune	28.9
40 ml. N. of Kingston	.. .. .	{ L.T.L.	35.1
		{ H.T.L.	33.5
		Dune	30.8
90 ml. N. of Kingston (Goolwa Barrage vicinity)	.. .. .	{ H.T.L.	63.0
		{ Dune	74.1
100 ml. N. of Kingston (Surfers' Beach, extreme north)	.. .. .	{ H.T.L.	81.6
		{ Dune	79.5

The progressive change in composition to the north is obvious and microscopic examination reveals the increase in solubles to be almost entirely due to quartz, although some silicate minerals are also present.

On this coast only one source is likely to be important in inducing the compositional change revealed, namely, those sediments introduced via the Murray River. Lesser sources are from coastal erosion in Encounter Bay, and from submarine outcrops of granite and/or Pre-Tertiary and Tertiary sedimentary rocks. Littoral drift would tend to spread these insoluble products particularly to the south from the Murray mouth which is eccentrically situated on the gently arcuate Coorong sea-beach.

A comparable state of affairs seems to have held throughout the period of "stranded beach" formation in the south-east. North of about Kingston sand blows extend increasingly further inland and finally become sufficiently massive to inundate, and obliterate, all earlier-formed coastal beaches. Moreover, as expected, the coarsely-grained aeolianite of the south gives away to finer-grained aeolianite with obviously increased insoluble (quartz sand) content, in this more northerly aspect.

North of Keith, siliceous sand sheets reach enormous dimensions, and extend for up to 150 miles inland. With one or two exceptions, the northern boundary of this sand lies about along the latitude of Tailem Bend and corresponds with the northern limit of the settling basins provided by the lakes before the Murray River mouth. More northerly accumulations extend east from about Jabuk and Karoonda. Two principal dune systems extend away from local fault escarpments and may possibly indicate former coast formation in earlier Plio-Pleistocene times, or fluvial activity.

A complication in the concentration of the heaviest siliceous sand sheets north of Keith is apparent with the Naracoorte Beaches. Whereas the lower level beaches, south of the Keith, cease to be smothered by later distributions of sands from successively younger beaches, these latter still produced large easterly distributions extending almost south to Naracoorte. The presence of granite knolls within these older coastal complexes, and associated outcropping older Tertiary fluvial sedimentary sources, may be sufficient source. There remain, however, the possibilities of a more southerly outlet, here, to the Murray River, as suggested also by the overdeepened (? eroded-valley) deposits of fossil shells of *Tintinara* as described by Tate (1898) and Howchin (1928).

#### (c) *Dominant Wind Directions*

Relatively "inexhaustible" supplies of fine sand, free to move under conditions of favourable climate (and other factors), may provide excellent "fossil" record of former wind patterns. Few areas could excel the south-east region in this respect.

In this paper it is not intended to anticipate a much more exhaustive treatment of the subject of "fossil wind regimes" as indicated by our Australian fixed desert dune systems which is now in an advanced stage of preparation by the writer. In this treatment particular consideration is given to "high impact force" winds (of 15 miles per hour or more) which are considered most efficient in transport of sand (other conditions of moisture content, vegetative cover, etc., being equal). Frequency-dominance of winds (in terms of direction) may or may not be a less important factor, assisting more in sweeping the interdune corridors and producing bias in lateral avalanche tendencies.

The dune patterns reproduced herein (Figs. 1 and 2) highlight the dominating influence of prevailing "high impact force" westerly winds during most of the periods of active sand transport. The long axes of all major sand accumu-

lations (inland from) West Avenue Range show this westerly factor very clearly. To the north this influence is overwhelming whereas to the south some oblique trends are superimposed on the still dominating westerly influence.

This westerly "dominance" is remarkable in view of modern wind patterns for this same area which show a strong prevalence, both in relative frequency and force of impact, for "south-westerlies". The sand drift lines of the modern Coorong coastal dune reflects this direction quite faithfully. *The most acceptable explanation for this seeming anomaly would appear to be that the present day wind pattern is strongly at variance with conditions obtaining during the Pleistocene Period when the inland blows were most active.* The dune pattern of the Karoonda-Pinnaroo zone is strongly reminiscent of the modern active dune system of the Waterhouse district in north-eastern Tasmania which are still active under conditions of high rainfall. A plentiful sand supply and strong force westerly winds are the controlling factors. These are sufficient to negative the influence of a strong, but quite comparable stunted vegetative cover in this region. (Both are areas of deeply leached sands apparently with low nutritive status of the soils.)

The directional change of dune structure near the Murray River mouth is from N90-100° E. to N35-45° E. This can best be explained by a significant migration of climatic belts in geologically recent times suggesting also that our modern climate may not simply be that of a "Pleistocene Interglacial".

It would appear, then, that the anticyclone belt is now removed further south. The so-called "Roaring Forty" belt (an unstable zone at the best of times) of high impact force westerly winds, and now passing over Tasmania, would appear to have been located at least 4 to 5 degrees of latitude further north. Moreover, there is no necessity to invoke arid periods to account for these desert-like developments, although drought and aridity may well have been significant factors. High impact force winds in areas of heavy and continuing sediment supply are adequate to overwhelm stunted vegetative cover and lead to dune formation.

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# **PRESUMED SUBMARINE VOLCANIC ACTIVITY NEAR BEACHPORT, SOUTH-EAST SOUTH AUSTRALIA.**

*BY R. C. SPRIGG, M.Sc.*

## **Summary**

Three, possibly four, submarine ridges lying transversely to the general contour of the continental platform opposite Beachport are interpreted to be submarine lava flows. A marginal submarine valley accompanies one or more of them. The heads of these presumed flows coincide closely with the epicentres of the 1897 and 1948 earthquakes, and this activity may represent the last phase of the late Quaternary basaltic volcanicity in south-eastern Australia.

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by R. C. SPRIGG, M.Sc.\*

[Read 11 September 1958]

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Three, possibly four, submarine ridges lying transversely to the general contour of the continental platform opposite Beachport are interpreted to be submarine lava flows. A marginal submarine valley accompanies one or more of them.

The heads of these presumed flows coincide closely with the epicentres of the 1897 and 1948 earthquakes, and this activity may represent the last phase of the late Quaternary basaltic volcanicity in south-eastern Australia.

## INTRODUCTION

Volcanoes have almost certainly been active beneath the sea opposite Beachport in late Cainozoic, perhaps even geologically Recent times.

Highly scoriaceous basalts have been collected washed up on beaches at many places from Beachport to Port MacDonnell. These may be the origin of local "old timer" rumours of volcanoes beneath the sea in this vicinity. Some have contended that the basalts came from greater distances, and the inevitable "clinkers" brought in with such samples, and also one example of imported basalt ballast, dumped at local seaports, rather more confused the issue.

The writer, while an officer of the South Australian Geological Survey, became interested in the fascinating possibility of submarine volcanicity in this vicinity, during prolonged field activities in the coastal zone during 1949-51, but at the time decided that the available evidence was insufficient. However, Captain Little, commander of the survey ship Lachlan, with whom the writer was associated during the Robe Harbour investigations, undertook several echo sounding traverses across the local continental shelf, and reported a submarine eminence off the coast between Rube and Beachport which appeared suggestive. This "peak" has been located on the latest hydrographic charts of the area which form the basis of this contribution. Of special interest is that this position corresponds closely with the epicentres of the 1897 and 1948 earthquakes, and also ties in with other anomalous submarine topographic features of the immediate vicinity.

### *Late Cainozoic Volcanicity*

Readers are referred to publications by A. V. G. James (1949) and R. C. Sprigg (1952) for summaries of volcanic activity in the local hinterland (Fig. 1). A roughly east-west volcanic belt extends across southern Victoria into south-eastern South Australia, ending rather abruptly, as far as outcropping evidence goes, in Mt. Muirhead, in the Mt. Burr range. Two solitary centres of late Tertiary activity occur much further to the north-west on Kangaroo Island. These groups are the so-called "Newer Volcanics" as distinct from earlier Tertiary volcanicity.

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\* Geosurveys of Australia Limited.





Fissure eruptions played a major role in the Victorian activity with the extrusion of basalt sheets covering more than 10,000 square miles over the western district plains and highlands. Near Portland, coastal eruptions poured out lava streams which even now can be traced across the coastline out along the sea floor, far out to sea.

In South Australia the activity was entirely basic, and the various vents can be related to presumed lines of fissuring, although true fissure eruption is not obvious. Small flows usually preceded cone formation, but the rapid accumulation of steam quickly led to the growth of large explosion craters.

In the Mt. Gambier vicinity, the earlier of these late Tertiary volcanoes, as exemplified by Mts. Burr and McIntyre, are considered to be late Pliocene to Early Pleistocene phenomena (Sprigg, 1952), and the later group by Mt. Gambier are late Pleistocene. Other writers have placed the activity still later, and N. B. Tindale and others, in drawing attention to possible references in local aboriginal legends have suggested very recent activity. This is not impossible, as even a short cycle of activity could well span the time interval concerned.

#### *Late Cainozoic Faulting*

Brief mention of faulting during late Tertiary and Quaternary times is important for its possible bearing on recent earthquake activity in the area.

Minor late Tertiary faults occur throughout outcropping Tertiary limestones in the Mt. Gambier area. They conform well with the major geological structural pattern of the area, and the jointing (Sprigg, 1952), and mostly they strike W.N.W. or N.W. Fault downthrow is usually to the south-west, and the extent of movement is generally small. Loci of volcanic eruption may be aligned along some of these. One of these, the "Tartwaup" line, would appear to pass out beneath the sea near Beachport which is also the site of an unexplained extremely sharp positive gravity anomaly (Department of Mines, unpublished information).

#### *Earthquakes.*

In view of the known late Cainozoic volcanic activity, and the considerable arching (upwarping), occurring in the south-eastern area (Sprigg, 1952), it is not surprising that two of the State's major earthquakes have been centred in this area in historic times. The first occurred on May 10th, 1897, and the second on April 8th, 1948.

Mr. G. F. Dodwell (1909), the late Government Astronomer, in describing the 1897 earthquake wrote that "tremors in the vicinity of Kingston . . . continued at intervals for some months, all appeared to point to a focus in the ocean somewhere west of that neighbourhood". The earthquake showed a large epicentral area and was recorded over southern Australia from Streaky Bay and well into Victoria. An isoseismal map (Fig. 2) prepared at the time suggests an epicentre off the coast near Beachport. The disturbance was accorded the value 9 on "Mercalli" scale.

According to local reports by persons still living, the shock dislocated the lighthouse machinery at Cape Jaffa, throwing the light off its beam and spilling the mercury at the base of the lamp. A large mass of acolianite nearby was split, and portions collapsed into the sea. To the north-west of Mt. Benson, opposite Nullock bark mill, the travertined limestone was cracked deeply. According to Mr. F. Winter, a local resident, the tremors continued for some weeks.

The more recent tremor of 1948 had its epicentre beneath the sea 10 miles north-west of Beachport, in much the same place as the 1897 earthquake. The shock was less severe, even though it was felt as far as 250 miles away. At Beachport, it cracked buildings, stopped clocks and dislodged crockery from

shelves. Nearer Adelaide the tremor lasted from a few seconds to five minutes, and in some areas it was preceded by low rumblings.

*The Evidence from Submarine Topography*

Lt. Commander Little's report of a rock eminence rising to 13 fathoms, but lying approximately on the trend of the 25 fathom contour, raises considerable

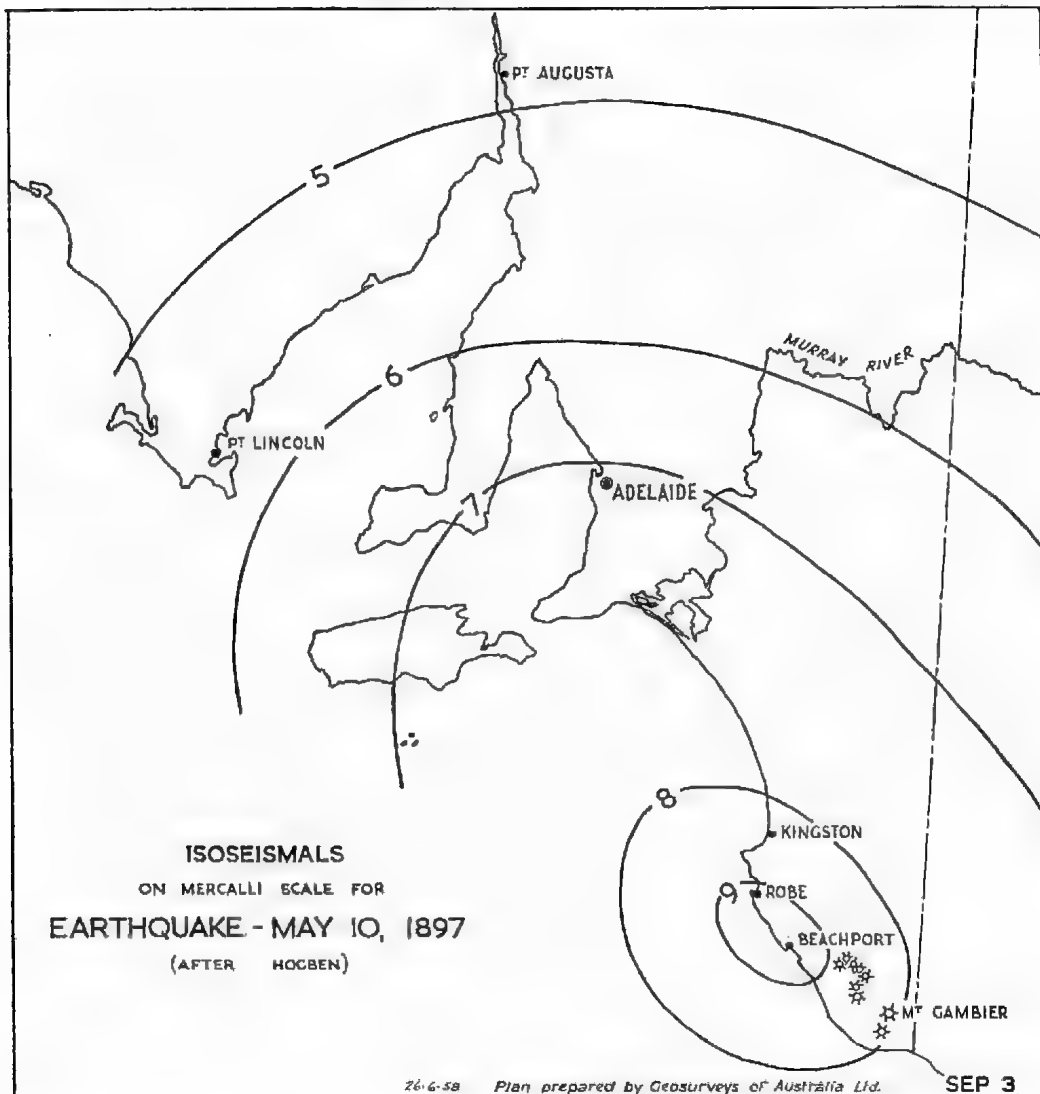


Fig. 2

interest. The continental shelf in this vicinity is at about its narrowest expression in South Australia. The trend of its outer margin is very direct, and almost due north-west. A general contouring of the depth soundings (Fig. 3) produces a gently sloping surface, steepening rapidly as it approaches the 100 fathom line, and thereafter plunging increasingly rapidly into the Jeffrey abysmal deep. Information is sufficient to show the broad form of this shelf quite clearly

except in a few zones. While appreciating the effects of personal bias, most of the contouring is reasonably smooth, and can be readily reproduced by independent investigators. However, several obvious anomalies stand out clearly. Three

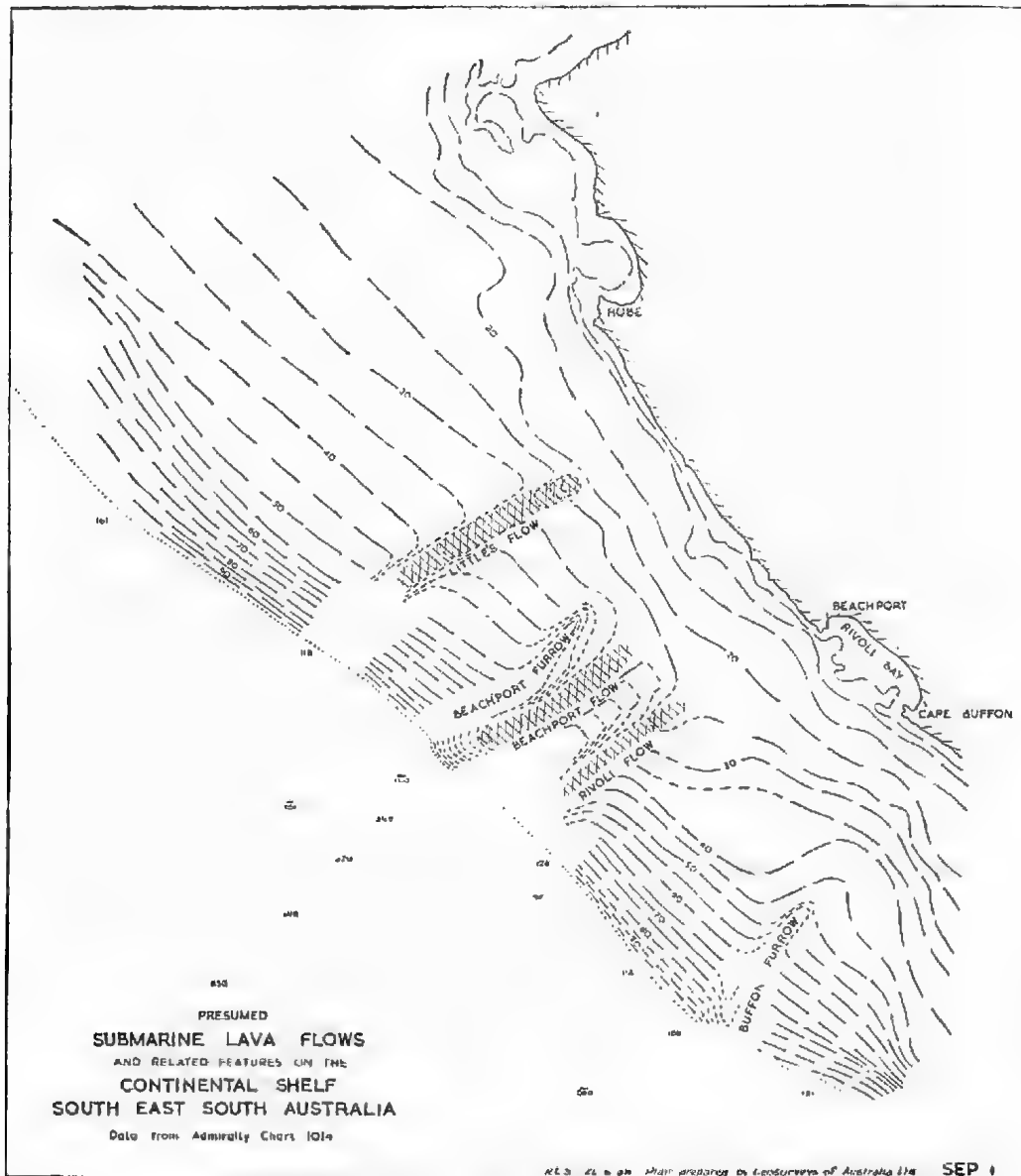


Fig. 3

transverse ridges, and possibly a fourth, interrupt the trend of the general sea floor contour boldly. In addition, valley-like depressions margin two of these features.

The eminence recorded by Lt. Commander Little represent the apparent abrupt landward termination of one of the ridges. Down-slope, it appears to

continue as a ridge for at least 12 miles, and is elevated 30 to 60 feet or more above its surroundings. Unfortunately, the density of soundings is insufficient to be more precise as to its exact morphology. The ridge is clearly elongated across the continental platform, in the direction of the steepest slope which is also transverse to the grain of faulting on the adjacent mainland. It is proposed to call this feature "Little's ridge". The upper (?) termination of this feature lies near the projected 25 fathoms contour, where it also appears to have its greatest differential elevation above the local sea floor (summit at 13 fathoms). This point is approximately 17 miles N60W of Beachport and 7 miles from the nearest coast. There appears to be no deviation of the recently surveyed 100 fathom line opposite this feature and it is presumed not to extend that far.

A second prominent ridge structure also lying transverse to the general contour of the shelf, occurs almost due west of Beachport. This will be termed the Beachport ridge. The soundings suggest this to be similarly elevated 60 to 100 feet above the projected level of the local platform. In the absence of suitably positioned soundings, the nature of its "head" is unknown. This ridge almost certainly crosses the 100 fathom line, for the marine charts show a clearly intended and definite outward bulging on the line at this situation. (This line was resurveyed in "continuity" by the "Lachlan" and replotted accurately.) The structure has elongation of twenty miles or more. A third ridge, apparently only slightly less conspicuous, lies a few miles to the south; its form is quite comparable. It is termed the Rivoli ridge.

On the northern margin of the Beachport submarine ridge there exists a deep trench, apparently also trending in the direction of steepest slope. This appears to be an erosional feature, and the few random soundings centred on it indicates overdeepening to 100 feet or more. The valley may be of the nature of a miniature submarine canyon, but more evidence is required to justify this conclusion. The valley to the south of the Beachport ridge appears not to have been overdeepened, rather it appears to be present by virtue of the existence of the ridges on either flank.

Directly south of Beachport distant approximately 20 miles, there is yet another associated ridge and valley topographic "anomaly". The evidence is meagre in view of the paucity of local soundings, but the general indication is similar to the foregoing. Its position is indicated on the plan. Interpretative statistics on each of these incompletely known features is given in Table 1.

TABLE 1.

Name of Submarine feature	Min. dist. from coast (in miles)	From Beachport		Length (miles)	Max. inferred elevation difference (in feet)
		Distance (miles)	Direction		
Little's ridge	7	17	N60W	14+	60
Beachport ridge	13½	13½	S85W	16+	100
Rivoli ridge	11	12	S60W	10+	100
Northumberland ridge	22	26	S15W	(?)3	60
Beachport groove	13	17	due W	?	90+
Northumberland groove	15	20	S5W	?	90+

### INTERPRETATION

Submarine earthquakes in 1897 and 1948 indicated epicentres to the north-west of Beachport distant some 10 to 20 miles. This general zone encompasses portion of the local continental shelf which carries several prominent ridge struc-

tures consistent in form with submarine lava flows. The structures are remarkably persistent, extending for 10 to 20 miles or more in the direction of maximum sea floor slope. The more northerly or "Little's" submarine ridge on present information has relatively greater prominence at its head, indicating perhaps restricted erosion, and suggesting very "youthful" characteristics, if the volcanic interpretation is correct. This location corresponds very closely with the calculated epicentral location of the 1897 earthquake. The 1948 epicentre admittedly also very approximately located is placed somewhat nearer to the head of the Beachport submarine ridge.

The nature of the (?) canyoning on the northern side of the Beachport submarine ridge is little known. It is possible that submarine density currents have been concentrated about the former sea floor anomaly and have lead to active erosion by bottom density currents. As the landward portion of the platform consists of Tertiary and Mesozoic sediments to more than 4000 feet depth, these soft sediments are also predicted for the platform edge and would be readily eroded.

Outcropping rock is reported on three of the four ridge structures, even though the adjacent continental platform surface is almost exclusively of sand, shell or "coral" (? polyzoa). This supports the lava flow interpretation, which in the light of all the available evidence appears logical. The flows would be conceived to have had "tunnel" form with the chilled lava surfaces providing crusts to insulate lava continuing to flow. Portland vents were spread rather more and produced wider and less regular flow associations. Relative sea floor elevations of the order of 100 feet above the surroundings were produced. The lava flow within Portland Bay originated on the land, but the position of the sea margin at the time is not known. Its course beneath the existing sea is clearly defined (Fig. 4). In its landward extension this flow has left some very fine elongate lava caves where the central liquid lavas had drained away.

### CONCLUSIONS

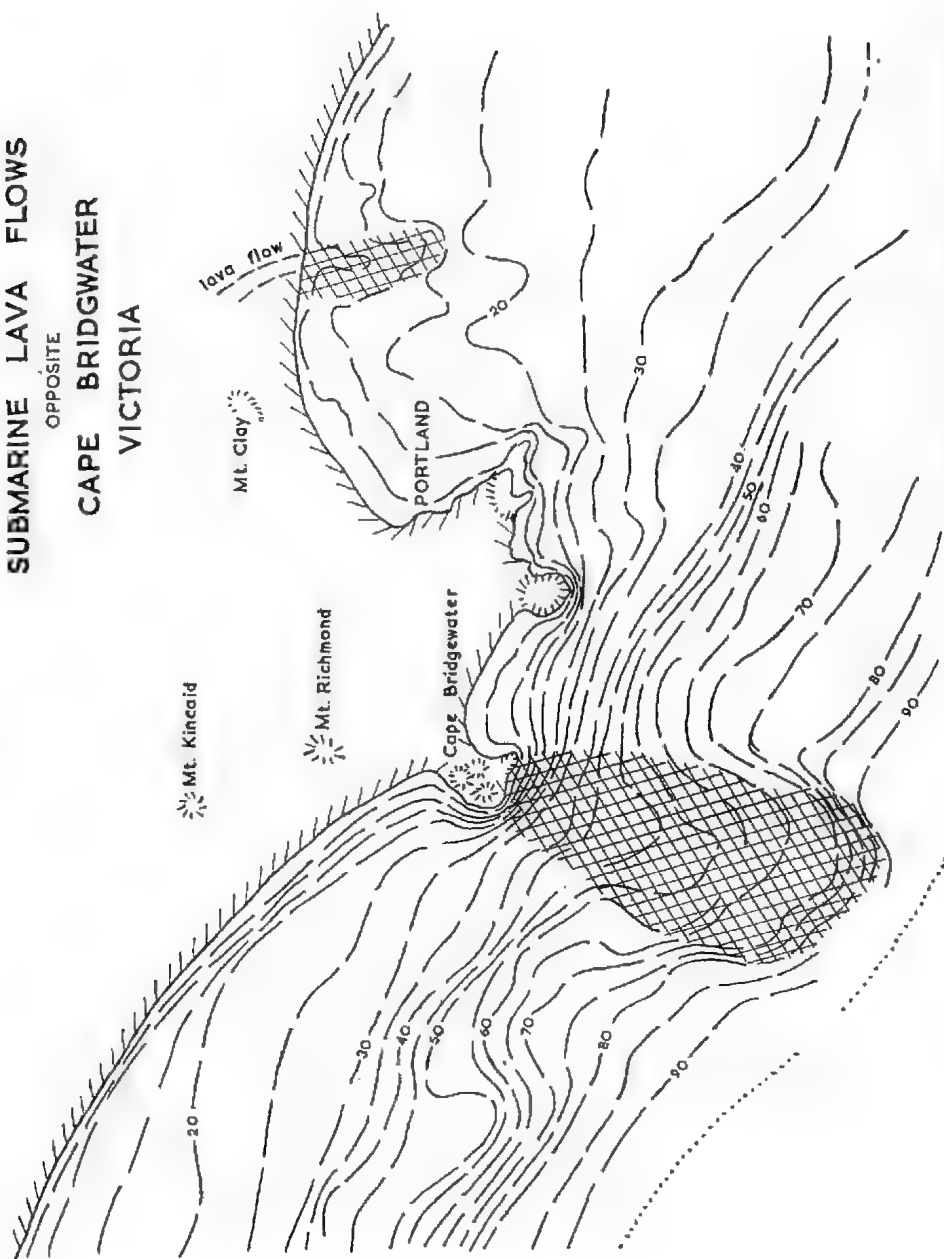
Three, and possibly four, presumed submarine lava flows erupted opposite Beachport in late Cainozoic times. The earthquake epicentres of the 1897 and 1948 correspond with these positions, and scoriaceous basalt has been washed upon the beaches along the local coast. The flows are of great length (10 to 20 miles or more) and one of them (the Beachport flow) is margined by a deep trough on its northern side, possibly by submarine scouring by marine bottom density currents.

There is no evidence, for or against, extrusion of any of these presumed flows during a low level phase of the sea. In either case, the lower portions of the flows must have been below sea level even at the height of the generally accepted 40 fathom or 240 feet maximum lowering. The Beachport structure displaced the 100 fathom line markedly to seaward, a fact which has been clearly recognised in drafting the latest hydrographic charts. A lowering of existing sea level by about 80 feet would be sufficient to expose the head of Little's "flow".

It is presumed that the "flows" belong to the Mt. Gambier-Mt. Schank phase of latest volcanicity, and in view of the associated seismic activity, may be the latest of them all.

There is a need for more detailed echo sounding surveys to fully elucidate these structures, and grab sampling of rock fragments would quickly verify the presumed volcanic nature. A search for volcanic glass or other material on the open beaches near Beachport may also help confirm these opinions.

**SUBMARINE LAVA FLOWS  
OPPOSITE  
CAPE BRIDGEWATER  
VICTORIA**



SEP 2

R.C.S. 23 5 58. Plan prepared by Geomorphs Aust. Ltd.

Fig. 4



## ACKNOWLEDGMENT

Appreciation is expressed for the kind co-operation of Mr. T. A. Barnes, Director of Mines, South Australia, in making available the block reproduced as Fig. 1 herein.

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# **THE CAMBRIAN-PRECAMBRIAN BOUNDARY IN THE EASTERN MT. LOFTY RANGES REGION: SOUTH AUSTRALIA.**

*BY R. C. HORWITZ, B. P. THOMSON AND B. P. WEBB*

## **Summary**

This paper presents the results of recent mapping by the Geological Survey of South Australia in the eastern Mt. Lofty Ranges. The area covered forms portion of the Adelaide, Echunga and Milang Sheets (1:63, 360 scale). In the north and south of the area, field evidence establishes an unconformity between Adelaide System sediments and younger Cambrian sediments. An attempt is made to locate the base of the Cambrian in the central region where both sequences are conformable. The stratigraphy of the Adelaide System and the lowest beds of the Cambrian, including the Kanmantoo Group up to the Nairne pyrite formation, is outlined. The facies variations of these sediments are described.

# THE CAMBRIAN-PRECAMBRIAN BOUNDARY IN THE EASTERN MT. LOFTY RANGES REGION: SOUTH AUSTRALIA†

by R. C. HORWITZ,\* B. P. THOMSON<sup>2</sup> AND B. P. WEBB<sup>3</sup>

[Read 11 September 1958]

## I. SUMMARY

This paper presents the results of recent mapping by the Geological Survey of South Australia in the eastern Mt. Lofty Ranges. The area covered forms portion of the Adelaide, Echunga and Milang Sheets (1:63,360 scale). In the north and south of the area, field evidence establishes an unconformity between Adelaide System sediments and younger Cambrian sediments. An attempt is made to locate the base of the Cambrian in the central region where both sequences are conformable. The stratigraphy of the Adelaide System and the lowest beds of the Cambrian, including the Kanmantoo Group up to the Nairne pyrite formation, is outlined. The facies variations of these sediments are described.

### (a) History

Metamorphosed Cambrian sediments, now known as the Kanmantoo Group, form the extreme eastern flank of the Mt. Lofty Ranges. Until some seven years ago there was much doubt as to the age of these sediments, and the opinion was held by many geologists that they were either Archaean or Late Proterozoic. This was due mainly to inadequate regional mapping. Earlier, Madigan (1925) had assigned a Cambrian age to these sediments farther south on the Fleurieu Peninsula, where the metamorphic grade is low.

Systematic mapping of the region on 1 inch to 1 mile sheets by the Geological Survey of South Australia led to the publication in 1951 of the Adelaide Sheet (Sprigg, Whittle and Campana).

The schistose metasediments on the eastern side of the Sheet were assigned to the "Kanmantoo Series" of (?) Early Palaeozoic age and the contact with Adelaide System rocks to the west was interpreted as a fault (the Nairne Fault). A similar interpretation was adopted for the Gawler Sheet (1953) and in part on the Echunga Sheet (1954).

Mapping of the Jervis and Yankalilla Sheets (Campana and Wilson, 1954, 1954a) represented a major advance in the understanding of the geology of the Mt. Lofty Ranges. This work clearly demonstrated the correlation of the Adelaide System sediments along both flanks of the Archaean core of the Ranges and the closure of these sediments to the south. The earlier Cambrian correlations of Madigan were confirmed and led to the proposal by Sprigg and Campana (1953) to the name "Kanmantoo Group" for the characteristic marine "flysch" facies overlying Cambrian phosphatic slates and limestones. A thickness of the Kanmantoo Group exceeding 30,000 feet was recognized on the Jervis Sheet. This great thickness suggested to Sprigg and Campana that the upper boundary of the Kanmantoo Group may extend into the Ordovician.

As a result of preliminary mapping on the Milang Sheet in the Ashbourne-Mt. Magnificent area, Campana and Horwitz (1956) interpreted the Kanmantoo

\* Geological Survey of South Australia.

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Group as a transgressive sequence on the (?) Cambrian and older rocks. One important result of this interpretation was the inference that the eastern boundary of the Adelaide System in the Mt. Charles area (Adelaide Sheet) and further north was marked not by a fault (the Nairne Fault) but by an unconformity with the younger Kanmantoo Group. More detailed mapping on the Milang Sheet later led Horwitz (1958) to the conclusion that both the Kanmantoo Group and basal Cambrian were transgressive, viz.:—

"Towards the east a great thickness of detrital rocks are found . . . It is a deeper geosynclinal Cambrian equivalent and transgressive on the Adelaide System. In this region, changes of facies also affect the Adelaide System."

Unpublished mapping by Coats on the Truro Sheet demonstrated that the basal Cambrian (Angaston and Stockwell marbles) and overlying Kanmantoo sediments were best interpreted to be transgressive on the Adelaide System.

Kleeman and Skinner (1958) do not accept the evidence for Cambrian transgression on the Adelaide System and prefer to explain their field evidence in the Strathalbyn-Harrogate region as the result of complex facies changes in the upper members of the Adelaide System and arbitrarily place the base of the Kanmantoo Group at the Nairne pyrite formation, stratigraphically well above the base of the Kanmantoo Group as established by the Geological Survey.

Horwitz commenced field work on the Milang Sheet in 1954, initially under the direction of Campana. Horwitz subsequently mapped on this Sheet the stratigraphy and facies variations of the Adelaide System and the basal Cambrian sediments and lower members of the Kanmantoo Group and thereby was able to recognize an unconformity between Precambrian and Cambrian sediments.

In 1958 Webb mapped the Mt. Charles area (Adelaide Sheet). This mapping established relationships between the Adelaide System and basal Cambrian sediments, which can only be satisfactorily explained as an **unconformity**.

Thomson in late 1957 commenced a study of the stratigraphy of the Kanmantoo Group on the Milang Sheet and extended it north and south on to the adjoining sheets. This mapping proved that the Nairne pyrite formation, and a related shaley facies extended south from Macclesfield to the Southern Ocean near Victor Harbor (Encounter Sheet). The thick arkose formation below the Nairne pyrite formation was also found by Thomson to be one of the persistent major units in the whole of the exposed Kanmantoo Group on the mainland. All three writers have examined together numerous sections of the Marinoan and Lower Cambrian on the Echunga and adjoining sheets.

The recent mapping of the Kanmantoo Group on the Milang and Encounter Sheets was done in collaboration with A. R. Crawford. Valuable and enthusiastic assistance was given by University students K. J. Mills, I. R. Pontifex and R. G. Brown.

#### (h) *The Problem of the Base of the Cambrian*

Daily (1956) gives an excellent account of this problem as applied to the South Australian Cambrian generally. Lower Palaeozoic fossils have not yet been recognized on the eastern side of the Mt. Lofty Ranges. This fact makes the positioning of the base of the Cambrian in that region a task involving strict attention in the field to the mapping of stratigraphy, lithology and structure of the sedimentary units. This work must be extended to a regional scale before even fairly reliable conclusions can be drawn. The writers believe that this stage has now been reached. Restriction of observations to small local areas is inadequate and misleading because of facies changes in both Cambrian and

Precambrian sedimentary units. Another factor to be considered is the variation in grade of regional metamorphism.

The base of the Cambrian on the western side of the Mt. Lofty Ranges at Sellick Hill has been taken by Campana and Wilson (1954b) to occur below a dominantly limestone sequence, the upper member of which contains Lower Cambrian fossils including *Archaeocyatha*. Daily (1956, p. 134; Horwitz and Daily, 1958, p. 54) on palaeontological evidence suggests that this approximates to the base of the Cambrian. The Sellick Hill limestone sequence or its metamorphosed equivalent is overlain by phosphatic shale. In this paper these two units will be referred to as the "basal Cambrian". At Carrickalinga Head on the Yankalilla Sheet, Campana and Wilson (1954a) found the phosphatic shale to be overlain by a greywacke-shale sequence which they took to be the basal member of the Kanmantoo Group. They found this sequence to be preserved in a structurally complex area on the Jervis Sheet to the south where the phosphatic beds finally turn north across the axis of the regional anticline and continue up the eastern flank to the vicinity of Delamere.

Sprigg and Campana (1953), in dealing with the Kanmantoo Group on the eastern side of the Ranges, tentatively correlated the Macclesfield marble horizon with the basal *Archaeocyatha* limestone.

Subsequent mapping on the Milang Sheet has enabled more precise correlations to be made. Horwitz (1958) mapped a marble similar to that at Macclesfield in the Finnis River Gorge near Mt. Magnificent. This marble overlies a black phosphatic and pyritic shale which can be reasonably correlated with the basal Cambrian phosphatic shale on the Yankalilla and Jervis Sheets where it overlies the *Archaeocyatha* limestone. The Finnis River marble is, therefore, on the basis of this correlation within the Kanmantoo Group. Similarly, it is believed that the Macclesfield marble is a member of the Kanmantoo Group because it is stratigraphically 2000 feet above the Macclesfield quartzite (Plate 3). Near Ashbourne this quartzite is immediately overlain by about 150 feet of black pyritic and (?) phosphatic slate, which is here correlated with the phosphatic shale at the base of the Kanmantoo Group. This slate dies out to the north of Ashbourne where it either lenses out or changes facies to a thin-bedded greywacke.

In the Ashbourne area, Horwitz (1958) recognized the Hallett Arkose formation of the Marinoan Series. This observation showed that the underlying marbles there, previously interpreted as (?) Cambrian (Campana and Horwitz, 1956) belonged to the Brighton Limestone formation of the Sturtian Series.

These findings narrowed considerably the problem of locating the base of the Cambrian in this region and at the same time presented strong evidence for a Cambrian (pre-Kanmantoo Group) transgression on the Adelaide System rocks.

Since the necessarily generalized definition of the Kanmantoo Group by Sprigg and Campana (1953), many geologists have tended to associate "greywacke facies" solely with the Kanmantoo Group. Horwitz (1958), however, has found in the Bull Creek-Ashbourne area that a restricted greywacke facies occurs in association with the Marinoan Hallett Arkose and also locally deeper in the Proterozoic sequence. This is generally in contrast to the Proterozoic facies on the western flank of the regional anticlinorium.

The interpretation of Kleeman and Skinner (1958), however, represents an extreme development of this concept. By shifting the base of the Kanmantoo Group upwards to the base of the Nairne pyrite formation, and including the underlying arkose and greywacke sequence in the Adelaide System, they

have made stratigraphic correlations which are not compatible with field evidence for the region.

(c) *The Scope of the Paper*

In this paper an attempt is made to locate the base of the Cambrian sediments in the region between Mt. Magnificent (Milang Sheet) and Mt. Charles East (Adelaide Sheet), a distance of about 34 miles. The purpose of this study is to provide a basis for fixing the Precambrian-Cambrian boundary for the future publication of the Barker and Adelaide Sheets of the 4-mile series of Geological Atlas of South Australia. The emphasis has been on lithological and stratigraphic observations. The interesting structural details, which are readily available in the field, are described only in so far as they have a bearing on the solution of local stratigraphical problems. No attempt is made here to deal fully with the variations in metamorphic grade which show a general increase from south-west to north-east. The original sedimentary character of the rocks at the northern end of the area are in many cases still readily recognizable in the field. Very useful aid has been given, particularly in the classification of some of these rocks, by petrographic studies carried out in the Mines Department laboratories both personally by and under the direction of A. W. G. Whittle.

### III. GEOLOGICAL EVIDENCE

(a) *General Lithology, the "Kanmantoo Facies" and "Adelaide System Facies"*

The much abused term "greywacke" has been loosely adopted by many South Australian geologists as synonymous with the Kanmantoo Group rocks. Greywackes (as defined by Pettijohn in 1957) appear to be most abundantly developed in the Kanmantoo Group rocks immediately above the Nairne pyrite formation. Below this formation, exclusive of thin, fine-grained phyllites members, there are local greywacke units and a variety of sediments covering a range of grain size and composition from sub-greywacke to arkose. Similar compositions have been found by Forbes (1957) for his Strangway Hill Beds, Inman Hill Formation and Brownhill Beds in the Grey Spur region which lies in the south-western portion of the Milang Sheet and extends on to the Encounter Sheet. All these beds have subsequently been demonstrated to belong to the Kanmantoo Group.

These sediments have a variety of field characteristics which may be summarized as follows:

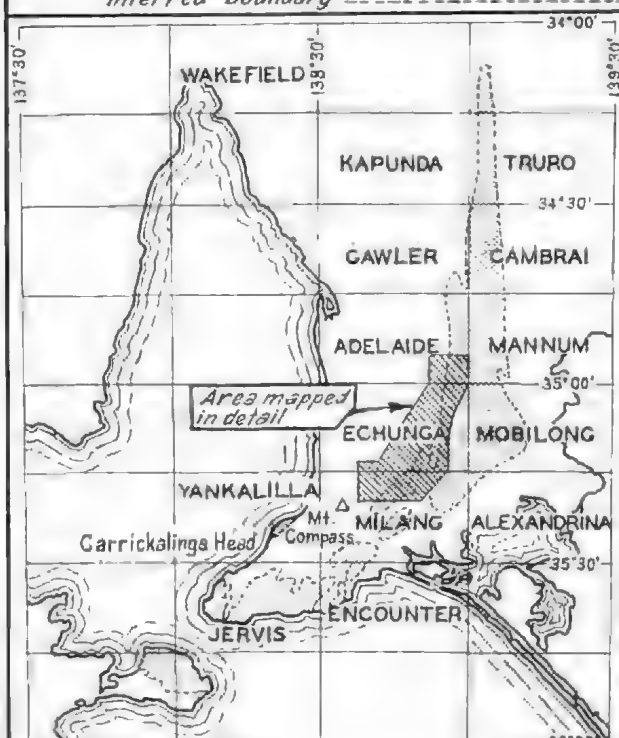
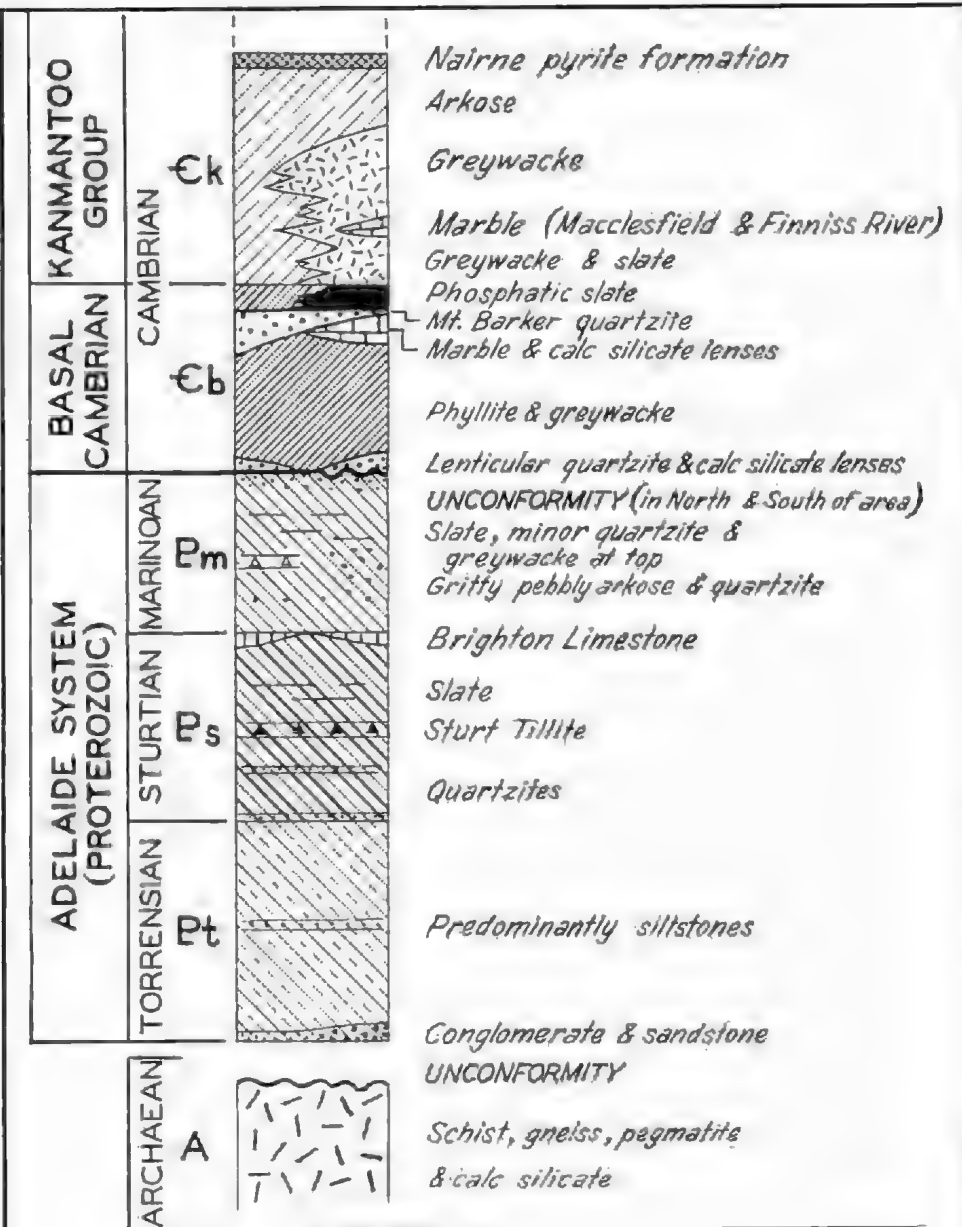
(i) *Colour*. Drab grey on weathered surface. Often finely mottled by disseminated ferromagnesian minerals.

(ii) *Texture*. Homogeneous and granular texture is a feature of thick-bedded members. When struck with a pick these rocks do not generally fracture readily, due to the "woody" character of the rock structure. This "woody" character is presumably due to the binding ability of the fine-grained matrix in which the detrital grains are set. On weathered surfaces the outer layer of the rock may be slightly friable, particularly if close to the Tertiary laterite level.

(iii) *Outcrop Shape*. Generally, shapes are rounded to sub-rounded, depending on grain size, silica content and degree of cleavage or schistosity developed.

Rocks of the Kanmantoo Group are generally of the above type, but, in the area dealt with in this paper, local horizons and lenses of sediments with similar characteristics occur throughout the Adelaide System. In this paper the term "Kanmantoo facies" is used to include all such rock types. Such occurrences in

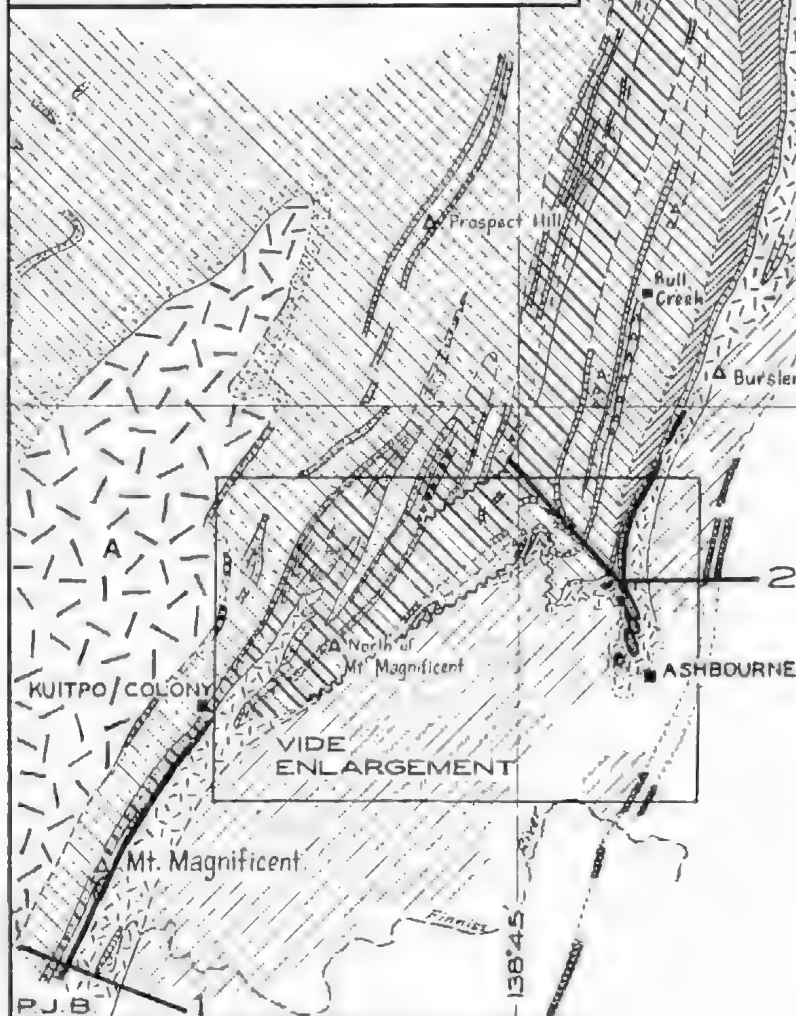




Sheets mapped (inc. unpublished) ... TRURO

Kanmantoo Group

Location of columnar sections shown in Plate III. .... 4



**GEOLOGICAL MAP**  
OF  
PORTION OF EASTERN MT. LOFTY RANGES BETWEEN  
MT. CHARLES & MT. MAGNIFICENT  
SHOWING CAMBRIAN-PRECAMBRIAN STRATIGRAPHY



Compiled from Geol. Survey S.A. 1 mile series geological maps, and later mapping by R.C. Horwitz, B.P. Thomson & B.P. Webb.



Proterozoic time heralded the general change to unsorted sediments, which developed in the vicinity of the Mt. Lofty Ranges and extended an unknown distance to the east in Cambrian time.

The normal "Adelaide System facies" can be considered to occur in the type sections near Adelaide (Mawson and Sprigg, 1950).

Pelitic rocks form the greatest proportion of the whole Adelaide System sequence on the eastern side of the Ranges. This is clearly illustrated by the great thickness of approximately 20,000 feet of slate and siltstone in a total thickness of 31,700 feet as shown in the legend of the Adelaide Sheet, although it is now believed that more detailed mapping and structural interpretation will considerably reduce these figures.

The thickness of 10,000(+) feet for the Adelaide System shown in Plate II has been largely determined on the eastern side of the anticlinorium on the Milang Sheet. This agrees with recent measurements on the Echunga and Adelaide Sheets for Sturtian and Marinoan Series. Other features of the "Adelaide System facies", apart from the tillites, arkose and dolomites, are the hard, white quartzites with 75 per cent. or more quartz, associated with the Stonyfell Quartzite, the Sturt Tillite and the Hallett Arkose. Apart from the Mt. Barker-Maccesfield quartzite and lower minor members such quartzites do not occur in the Cambrian.

It is in the Marinoan that the "Kanmantoo facies" and the "Adelaide System facies" overlap and intertongue to the greatest extent.

#### (b) *Stratigraphy*

The generalized stratigraphy of the region is outlined on Plate I.

##### (1) *Archaean*

Campana and Wilson (1954b) describe these rocks on the Yankalilla and Jervis Sheets as schists, gneisses and stressed granites. Gneisses range from quartz-mica to sillimanite-garnet gneisses. Basic dykes and pegmatites, in part possibly of Proterozoic or Palaeozoic age, are also present.

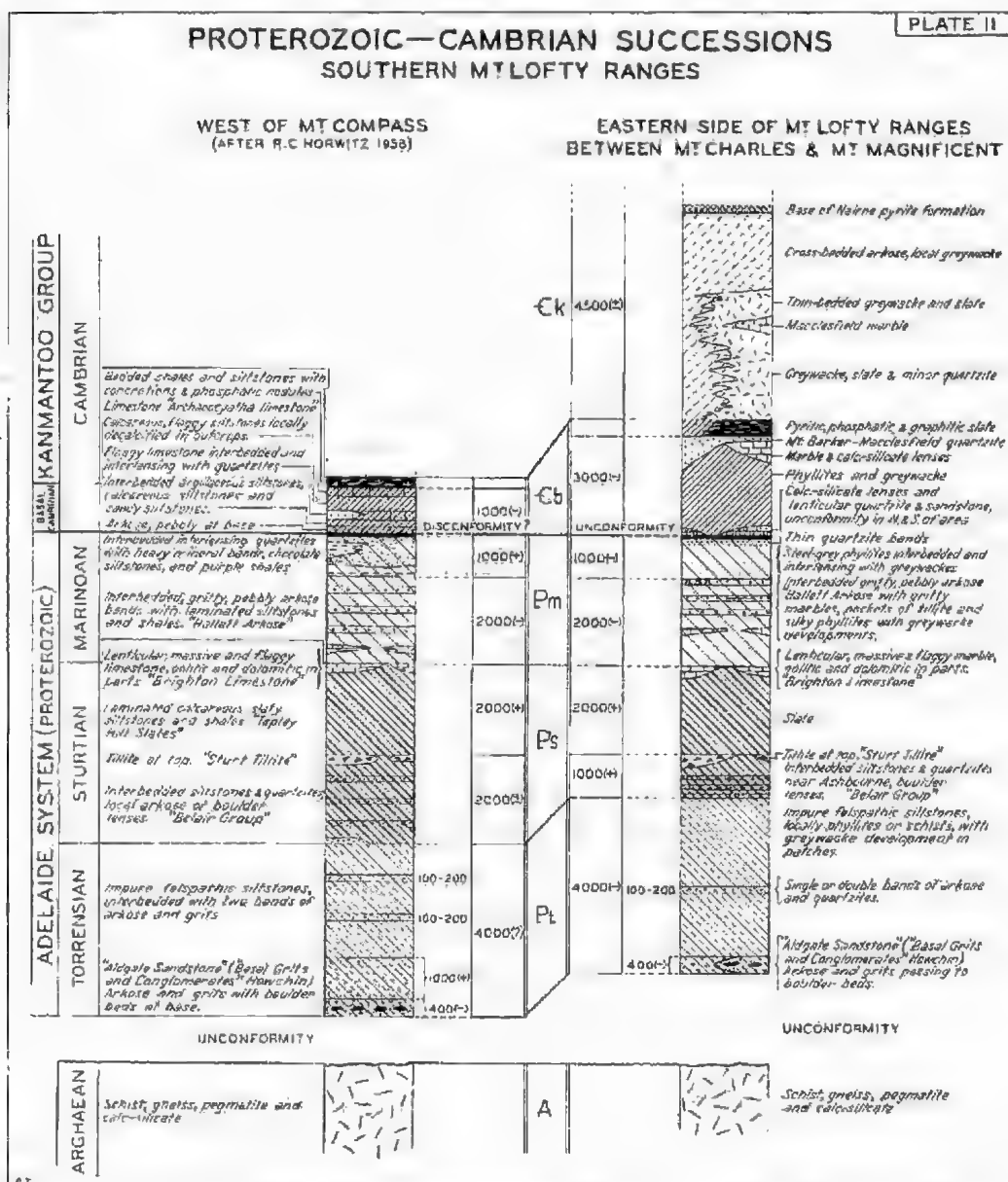
Strong schistosity is developed in the metasediments and in places in the basal beds of the Adelaide System. The metamorphic grade of the Archaean is generally much higher than the Proterozoic and Cambrian rocks, but has been to a large extent obscured by retrograde changes caused by Palaeozoic and earlier folding and shearing.

##### (2) *Proterozoic: Adelaide System*

The Proterozoic succession in the southern part of the Mt. Lofty Ranges on the Fleurieu Peninsula shows some interesting facies variations. As previously recorded by Sprigg, Whittle and Campana (1951), rocks to the west of the Archaean core differ in facies from those to the east. Despite these facies variations some good marker beds persist on both flanks of this structure (Mt. Lofty Anticlinorium of Campana, 1955a). The succession can be summarised as follows—further details being shown on Plate II.

(i) *Torrensian*. The lowest members are the Basal Grits and Conglomerates (Howchin, 1906) or the Aldgate Sandstone (Mawson and Sprigg, 1950). This formation varies in thickness from 200 to 700 feet. Boulders are usually present at the base. The basal formation is overlain, on both limbs of the anticlinorium by a sequence, less than 4000 feet thick, in which siltstones or their metamorphic equivalents (phyllitic siltstones or siliceous schists) predominate. There is, however, a difference, for on the eastern side of the Archaean core bands of greywacke are interbedded with the siltstones. All of these sediments are correlated with the Torrensian Series. The upper limit had already been chosen as such on the published sheets.

These sediments persist to the northern limit of the area here described, to the north and west of Mt. Charles where the metamorphic grade has converted them to quartzite-sericite-muscovite schists. Here, one specimen examined by



Whittle was found to have the composition of a greywacke and to contain traces of sillimanite.

(ii) *Sturtian*. The Torrensian Series is overlain by well marked bands of quartzite (usually three) with boulder beds and coarse arkoses, interbedded with slate and greywacke lenses.

Tillite sometimes overlies these beds. The quartzite and the tillite are correlated with the Belair Group and Sturt Tillite of the type section near Adelaide (Mawson and Sprigg, 1950). These lower beds of the Sturtian are very constant in facies on the Milang Sheet and on the eastern side of the anticlinorium measure 1000 feet in thickness. Further north the quartzites decrease in number, but persist to Mt. Charles East, where they are terminated by the Cambrian unconformity. Howchin (1929) records tillite in the upper members in the vicinity of Mt. Barker township.

Overlying these lower Torrensian beds is a constant succession, 2000 feet in thickness, of laminated siltstones and shales with limestone bands and lenses towards the top. These sediments, which are valuable markers, are correlated with the Tapley Hill Slates of the type area. Near the base of this sequence the slates are blueish in colour and show traces of pyrite. In a similar stratigraphic position, immediately south of Mt. Charles, a low grade schist was found by Whittle to have a typical greywacke composition.

Local marble lenses are interbedded with the Tapley Hill Slates which themselves are also locally calcareous. In the northern part of the area these beds are represented by flaggy calc-silicate rocks. The Sturtian Series ends with the Brighton Limestone, represented by a white marble, which persists along the strike for four to five miles in places, and may reach a thickness of over 100 feet.

(iii) *Marinoan*. The lowest beds of the Marinoan Series are arkosic sandstones, interbedded with silky phyllite, greywacke, gritty and pebbly arkose (Hallett Arkose) and gritty marble. These arkosic beds are locally lenticular, but combine to form a well-defined and easily recognisable unit reaching a thickness of over 2000 feet. In the northern part of the area in the vicinity of Murdock Hill calc-silicate horizons develop at the top of the sequence and are apparently truncated at the unconformity by the overlying Cambrian sediments. Of interest are the local pockets of tillite occurring with arkoses and greywacke in the vicinity of Mt. Barker Creek (Howchin, 1929) and near Bull Creek (Horwitz, 1958).

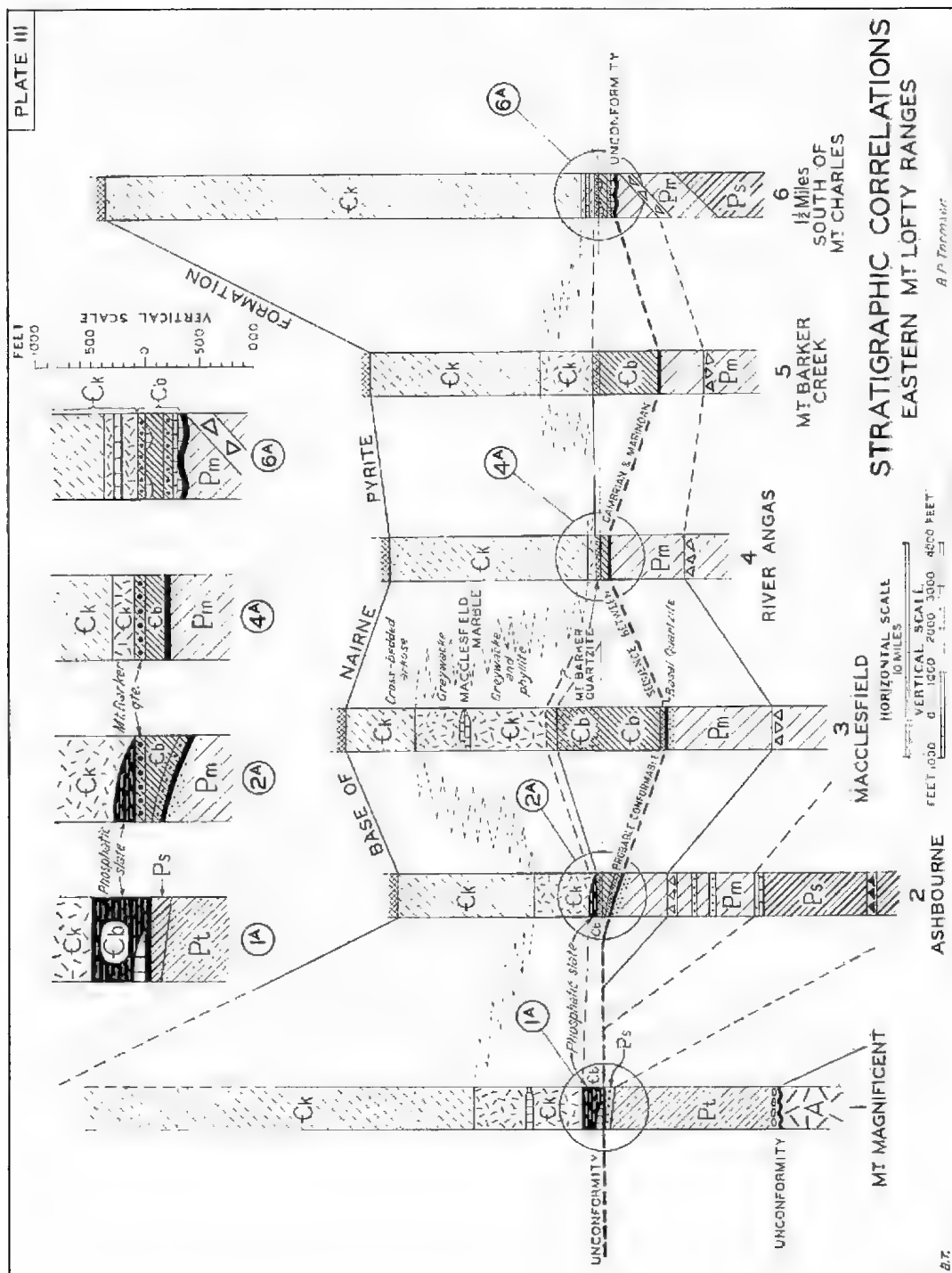
The upper sequence of the Marinoan Series is finer grained and is noticeably phyllitic throughout the region. Andalusite-staurolite schists develop in this unit to the north. The thickness varies from 1000 to 2500 feet, the maximum thickness being observed in the vicinity of Macclesfield (see Plate III). At the top of these beds, near Bull Creek, quartzite members, generally not exceeding one foot in thickness, occur and are interlensed with phyllite and fine-grained greywacke. These quartzites disappear to the north and are here provisionally interpreted as the thin eastern extension of the Pound Quartzite, a facies developed very extensively towards the north-west of this region. It is also possibly present on the western side of the anticlinorium as thicker sandy sequences that occur extensively at the top of the Marinoan (see Plate II).

### (3) *Basal Cambrian*

(i) *Mt. Magnificent-Ashbourne Area*. Since it is in this area that the starting point for the Cambrian correlation in the region under discussion is assumed, it will be discussed in some detail.

Phosphatic slate and underlying marble lenses which we correlate with basal Cambrian sediments are exposed in the bed of the Finnis River. This sequence continues north for three miles where it changes to fine-grained phyllitic greywacke which is folded in a tight syncline-anticline structure. The greywacke overlaps unconformably the underlying Sturtian quartzites which being more rigid were deformed by imbricate thrusting during the major folding process.

A north-east striking fault near McHarg's Creek is developed on the unconformity and the "Kannmantoo arkose facies" is there in contact with Marinoan



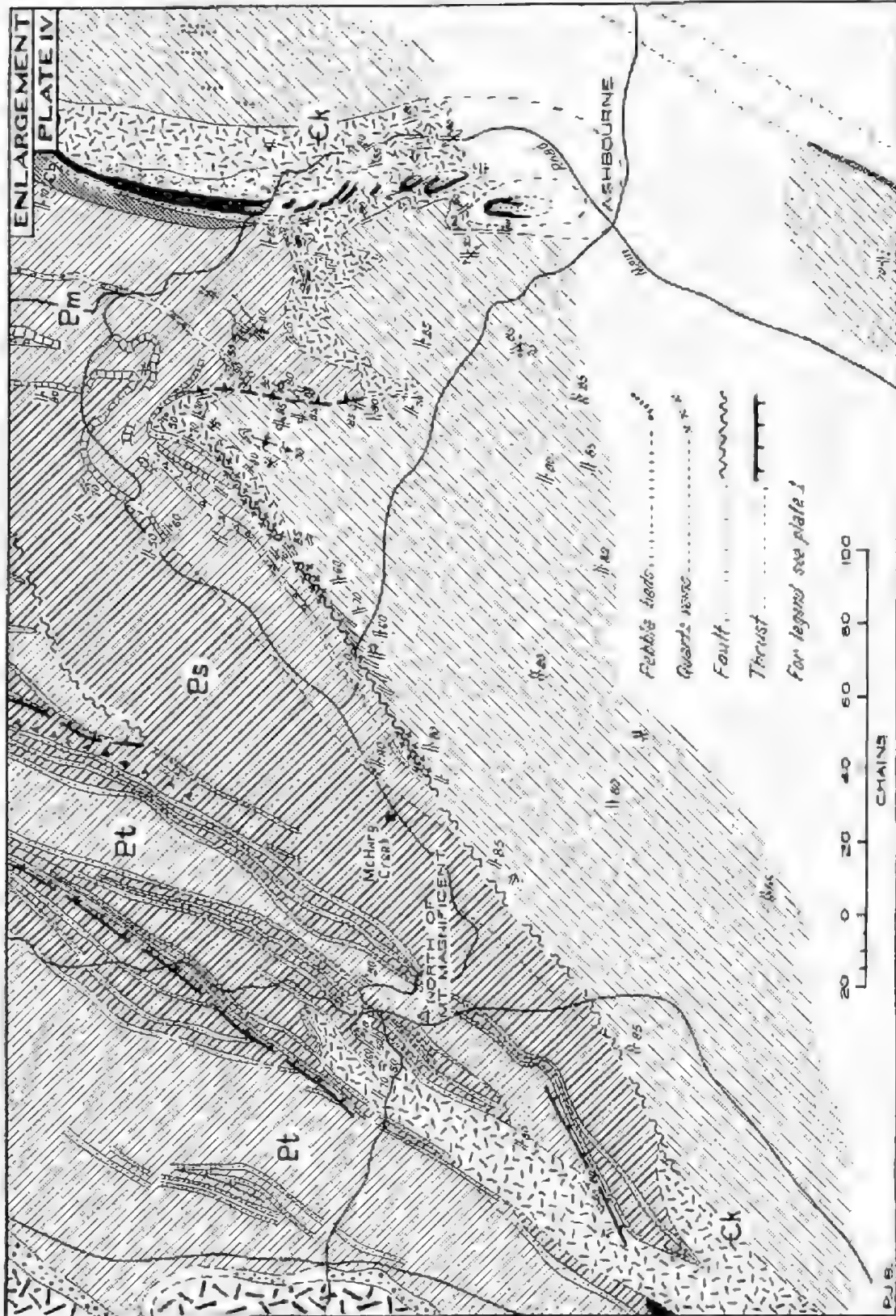
sediments. A dark phyllite, possibly equivalent to the phosphatic slate, emerges from the fault contact and is exposed in a syncline one and a half miles north-east of McHarg's Creek.

Overlying the phyllites are fine-grained greywackes which become coarser in grain size until the sequence is represented by coarse cross-bedded arkose.

The eastern limb of the syncline is sheared out to the south and develops into a steeply dipping north-south stretch-thrust. To the east of the thrust the structural setting is even more complex. Isolated exposures of black pyritic slate occur overlying thin (?) Cambrian quartzite west of the main road. This slate is believed to be the equivalent of the Mt. Magnificent phosphatic and pyritic slate. On the main road, one mile north of Ashbourne, the black slate is well exposed in a deep cutting, where it is folded into a tight anticline with a quartzite core. The slate is repeated in a succession of steep plunging anticlines which are disposed in an *en echelon* pattern to the south and finally plunge below the arkose of the Kanmantoo Group near Ashbourne. The slate finally emerges from this anticlinal environment as an east facing limb and persists for one and a half miles north of the main road cutting, where it is underlain by the Macclesfield quartzite as described above.

(ii) *The "Basal Quartzite"*. Northwards from the main road cutting the beds underlying the Macclesfield quartzite diverge in strike to the west and greywackes and interbedded slates appear in the sequence. The sequence appears to be continuous down to a lenticular quartzitic unit which is well exposed in outcrop at Bull Knob Trig. Below this quartzite, which is provisionally referred to as the "basal quartzite", typical Marinoan phyllites appear. The quartzite and related sandstones can be followed intermittently to the north around the Macclesfield syncline. About one mile east of Macclesfield the "basal quartzite" is exposed in the nose of the Strathalbyn anticline which at this point plunges gently south below andalusite schists containing minor greywacke bands. The unit reappears one and one-third miles south as massive quartzite in a domal structure, the result of a pitch reversal. Local calc-silicate minerals are here developed at the base of the quartzite. The quartzite can be followed for about one mile north along the eastern limb of the Strathalbyn anticline where it gradually changes facies to a massive greywacke. The greywacke in turn becomes increasingly phyllitic in character like the underlying Marinoan sediments and it cannot be located with certainty in the field at the latitude of Bugle Ranges. Structural evidence shows that the stratigraphic position of the basal member is located approximately midway between the Hallett Arkose to the west and the Mt. Barker quartzite to the east. At this stratigraphic level one mile east of Wistow, greywackes reappear, and continue north to the Mt. Barker Creek. Here a well defined greywacke and quartzite sequence is exposed which continues with interbedded phyllites up to the persistent calc-silicate bed at the base of the Mt. Barker quartzite. Quartzite, massive greywacke and arkose continue to one mile north of Nairne. Further north the formations thin gradually and converge in strike. The "basal quartzite" is represented by discontinuous lenses of white quartzite associated with lenses of diopside granulite rocks. These rock units persistently maintain a northerly strike to the northern edge of the area, in contrast to the general east-west strike of the Adelaide System rocks to the west.

(iii) *The Macclesfield-Mt. Barker Quartzites*. Massive quartzite is exposed about one mile north-west of Macclesfield where it reaches 1000 feet in thickness. It can be followed south-west to the northern boundary of the Milang Sheet as described above. This formation lenses out or intertongues with greywackes one and a half miles south-east of Macclesfield, on the eastern limbs of





the Macclesfield syncline. Tectonic thinning appears to have contributed in part to the disappearance of the quartzite. The greywackes at this stratigraphic level continue south and enter the complex folds that are part of the major structure comprising the Strathalbyn anticline. A massive quartzite outcrops two and a half miles south-east of Macclesfield. Analysis of the structure shows that this quartzite approximates closely the stratigraphic level of the Macclesfield quartzite.

The massive quartzite can be followed north for fifteen miles to the northern boundary of the Echunga Sheet where it forms the Mt. Barker ridge. On the Adelaide Sheet the quartzite is concealed by younger sediments south of Mordock Hill. Lenticular quartzites outcrop north-east of this point and the strikes gently converge to the north. In Inverbrachie Creek the most easterly quartzite has been taken to represent the Mt. Barker quartzite horizon. This formation is associated with calc-silicate lenses which may be correlated with the diopside granulite exposed in Mt. Barker Creek at the base of the Mt. Barker quartzite. This calcareous metasediment can be followed intermittently to the south for five miles. We believe that it is an echo of the more vigorous limestone sedimentation of the basal Cambrian in the Sellick Hill region. Considerable support is given to this interpretation from the regional geology to the north of Mt. Charles. A thick marble horizon, which underlies greywackes, occurs three-quarters of a mile east of Mt. Torrens. On the Gawler Sheet marbles also occur west of Mt. Kitchener. The thick marble sequence in the basal Cambrian on the Kapunda and Truro Sheets indicates a carbonate sequence comparable in thickness with the Sellick Hill area.

#### (4) *The Kanmantoo Group*

By definition the Kanmantoo Group commences at the top of the basal Cambrian phosphatic slate. Good sections are obtained in the Finnis River east of Mt. Magnificent and in the vicinity of Ashbourne (see Plate III). Here the lowest beds are lenticular massive greywackes interbedded and intertonguing with phyllites, the latter increasing in proportion in the ascending sequence. At 1200 feet above the base is the white marble lens of the Finnis River. At 2300 feet above the base, thick cross-bedded arkose suddenly appears in the sequence. The contact with underlying phyllites can be readily mapped to the north and south. In the Ashbourne section the same arkose appears at 1200 feet above the base, and is here 3000 feet thick.

North of Ashbourne the base of the Kanmantoo has been taken at top of the Macclesfield quartzite, although the precise location is probably several hundred feet above this level. In the Macclesfield section (Plate III, section 3) phyllites and greywackes extend for about 3300 feet above the quartzite and include the marble member which is approximately 200 feet thick. This marble may be contemporaneous with the Finnis River marble and also with a calc-silicate horizon reported by Kleeman (personal communication) one and a quarter miles north-east of Mt. Charles East. The arkose formation in the Macclesfield section is only 1600 feet thick. The proportion and thickness of the coarse arkose facies increases to the north until it occupies all the stratigraphic column between the Nairne pyrite formation and the Macclesfield-Mt. Barker quartzites as seen in the area between sections 4 and 5 on Plate III. In section 5 the basal Kanmantoo sequence is thin-bedded arkose and phyllite. The typical coarse cross-bedded arkose does not appear until 1200 feet above the base. The finer-grained facies appears to lens out completely to the south and in a large degree to the north. The thickness of the Kanmantoo Group sequence below the Nairne pyrite formation varies from 4400 to 5200



feet between sections 1 and 5. In these sections the coarse arkose varies from 1600 to 4700 feet. This range of thickness can only be satisfactorily explained as the result of facies variations within the sediments (as indicated on Plate III).

The 10,000 feet thickness of coarse arkose in section 6 and 10,000(±) feet in section 1 can be attributed largely to original sedimentary thickening. This is shown by the divergence of strike lines north-east of Murdock Hill.

### (c) Structure

#### (1) Sedimentary Structures

Minor sedimentary structures such as slump bedding are found in a few places in the greywacke facies of the Marinoan Series as also are fine scale cross-bedding and graded-bedding.

In the coarse arkose of the Kanmantoo Group both slumping and cross-bedding are developed in some localities on a large scale. Beds up to three feet in thickness may show intense slump folds and cross-bedding has an amplitude of up to four feet between topset and bottomset beds.

The most spectacular large-scale sedimentary structure is in the vicinity of McHarg's Creek near Ashbourne where a north-east contact between east-north-east trending Marinoan sediments and north-south trending Kanmantoo arkose marks approximately the boundary of a zone of rapid thickening in the arkose possibly related to a fault line which was active during sedimentation.

The geometry of the structure demonstrates that the hinge line, formed by intersection of bedding planes with the plane of the contact, plunges steeply south-east and that the present surface in this locality represents a section of the Cambrian basin. The contact has been the locus for later local faulting.

#### (2) Tectonic Structures

In the Mt. Magnificent-Ashbourne area the tectonic structures have their strongest development. East of Mt. Magnificent the incompetent Lower Cambrian sediments are tightly folded and strongly sheared between the Adelaide System quartzite and the Archaean core to the west, and the resistant block of coarse Kanmantoo Group arkose to the east. The arkose block has also been thrust against the underlying unconformity with the Adelaide System. Near Ashbourne, the right-handed *en echelon* of domes of basal Cambrian, although locally overturned in plunge, represents in miniature the regional pattern of folding. This is consistent with the zig-zag and elliptical patterns of *en echelon* folding described by Campbell (1958). The *en echelon* pattern is repeated along the axis of the Strathallbyn anticline which is a composite structure made up of numerous individual anticlines. These structures, however, are not as tight as those in the Ashbourne area.

The *en echelon* pattern is preserved on the Adelaide Sheet in the Mt. Charles area where the unconformity traces in plan a sinuous course reflecting the Paleozoic folding. The individual folds in the thickened Kanmantoo Group to the east appear to die out as they approach the unconformity, whereas the folds to the west in the Adelaide System appear to plunge below it. The pattern and degree of folding established in the Adelaide System prior to Cambrian sedimentation is difficult to establish. We believe that it was most probably monoclinial in character.

## IV. CONCLUSION

### (a) Validity of Stratigraphic Correlations

In the absence so far of fossil and isotope dating evidence for inferring a Cambrian age for the sediments in the area dealt with in this paper, the writers have accepted the lithological and structural evidence. An important key hori-

zon is the phosphatic slate of the Mt. Magnificent area. Evidence for accepting this as a member of the basal Cambrian is as follows:

(i) Considering the evidence in section. At about ten miles west of Mt. Magnificent in the Sellick Hill area, on the western side of the Mt. Lofty Anticlinorium, the Lower Cambrian calcareous sequence is overlain by the phosphatic shale horizon. A lithologically similar sequence, facing east, is observed east of the Mt. Magnificent quartzite, which is interpreted as marking an unconformity in this area, the limestone being restricted to small lenses at the unconformity.

(ii) Considering the evidence in plan. The cross-bedded Kanmantoo arkose has been followed south by one of us (B.P.T.) on to the Yankalilla and Jervis Sheets, where in the vicinity of Delamere, phosphatic slate and marble appear at approximately the same stratigraphic interval below the arkose as they do at Mt. Magnificent. From this point the succession can be followed with minor interruptions to the Sellick Hill locality. Field evidence north of the Adelaide Sheet has already been discussed (see "Basal Cambrian" above). The writers believe therefore that the most reasonable interpretation of the evidence now available is to include the Mt. Magnificent slate and marble in the basal Cambrian.

The dating of the "basal quartzite" as lower Cambrian in the area between Ashbourne and Mt. Charles has been influenced by the discovery of a gritty arkose (Horwitz, 1958) at the base of the Cambrian sequence on the Milang Sheet north-east of Sellick Hill. This arkose would imply a hiatus and change in condition of sedimentation in this area towards the end of Pound Quartzite time and possibly into the earliest Cambrian. We correlate this change and possible disconformity with the folding and erosion of the Adelaide System which took place farther east during this time interval. The possibility remains that the Macclesfield-Mt. Barker quartzite represents the equivalent of the Pound or ABC Range Quartzite. The writers consider this unlikely and assume that the unconformities exposed at Ashbourne and Mt. Charles are the result of contemporaneous transgression.

#### (b) *Tectonic History*

The tectonic history, commencing with the Upper Proterozoic, is summarized as follows:

- (1) Deposition of Torrensian sediments on Archaean.
- (2) Sturtian and Marinoan sedimentation and continued slight variations in stability in the region.
- (3) Local uplift and erosion of the Adelaide System in the Mt. Lofty Ranges region at the close of Marinoan time; probably due to positive movement of the Archaean core. Sedimentation continuous to the east during this period.
- (4) Transgression of Cambrian on the eroded and folded Adelaide System platform; relative increase in the rate of sedimentation to east and west of the present Mt. Lofty Anticlinorium.
- (5) Sedimentation of the Kanmantoo Group marked by the intermittent but relatively rapid subsidence over eroded areas of the Adelaide System.
- (6) Pre-Permian Palaeozoic orogeny; deep folding of the Adelaide System; metamorphism of the Kanmantoo Group and the eastern zone of the Adelaide System sediments; granite intrusions; positive movement of the Archaean basement.
- (7) Prolonged erosion of Pre-Permian mountain terrain and associated arching, warping and faulting with the formation of localized younger sedimentary

basins and continental areas. These phenomena are still active and are responsible for the present physiography of the region.

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# **A WIDESPREAD PLIOCENE MOLLUSCAN FAUNA WITH ANODONTIA IN SOUTH AUSTRALIA.**

*BY N. H. LUDBROOK*

## **Summary**

A shallow water molluscan fauna with large pelecypods including *Anodontia sphericula* (Basedow) is described from transgressive Pliocene sediments occurring from Fishery Bay on Eyre Peninsula to Moorlands in the Murray Basin.

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by N. H. LUDBROOK\*

[Read 11 September 1958]

## SUMMARY

A shallow water molluscan fauna with large pelecypods including *Anodontia sphericula* (Basedow) is described from transgressive Pliocene sediments occurring from Fishery Bay on Eyre Peninsula to Moorlands in the Murray Basin.

## INTRODUCTION

At widely separated localities in South Australia, thin, apparently synchronous Pliocene limestones and sandstones carry a fauna characterized by an abundance of large pelecypods. The most conspicuous and interesting is a large globular shell the size of a flattened tennis ball, casts of which readily weather out from the limestones. These globular casts have been variously known as *Dosinia greyi* Zittel and *Meretrix sphericula* Basedow, but the adductor impressions and the pallial line are those of the *Lucinidae*. The only complete specimen so far recovered consists of a pair of valves recorded by Howchin (1936, p. 7) from the Cowandilla Bore at 470-485 feet. From this specimen it has been possible to identify the genus *Anodontia* to which Basedow's species should be referred.

## DISTRIBUTION OF THE FAUNA

The molluscan assemblage has been identified from as far west as Fishery Bay on southern Eyre Peninsula to Moorlands in the Murray Basin. Many of the outcrops represent strand lines of the transgressive shallow seas distinguishing this part of the Pliocene. Deposition took place in shallow bays, the abundance of *Pectinidae* indicating sandy bottoms and of *Ostreidae* the existence locally of restricted conditions favourable to the development of thick oyster beds. Not all oyster beds occurring in the Murray Basin were contemporaneous with the present fauna. There has been a tendency to regard those of the western margin of the Basin as belonging to a single unit, but this is not so. The stratigraphic levels at which oyster beds occur still awaits the result of detailed mapping and examination of the vertical ranges and associated faunas of the three species which occur in the Loxton Sands and Norwest Bend Formation — *Ostrea hyotidoidea*, *O. sturtiana*, and *O. arenicola*.

Most of the Pliocene outcrops are very thin, seldom exceeding five feet in thickness. They were deposited in markedly transgressive seas. At both Fishery Bay and Moorlands the conglomeratic limestones overlap bedrock, of which pebbles up to small boulder size are caught up in the limestone. The probable margins of the sea at this time are indicated in Fig. 1; areas known to have been inundated are shaded.

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On *Eyre Peninsula* at *Fishery Bay*, at the south end of *Sleaford Bay*, 20 miles south-west of *Port Lincoln*, basement granite pebbles occur in limestone with molluscan moulds and casts of *Anodontia sphericula*, *Vasticardium submaculosum*, *Fulvia tenuicostata*, *Miltha hora*, *Antigona cognata*, *Cassis* (*Hypocassis*) *salisburyensis*, all of which have been identified from casts weathered from the matrix. This assemblage is represented in the molluscan fauna of the *Dry Creek Sands*. The material from *Fishery Bay* was collected by *R. K. Johns*.

The occurrence in *Deep Creek*, *Hundred of Poynton*, 20 miles south-south-west of *Whyalla*, has been described elsewhere (*Miles*, 1954, p. 25).

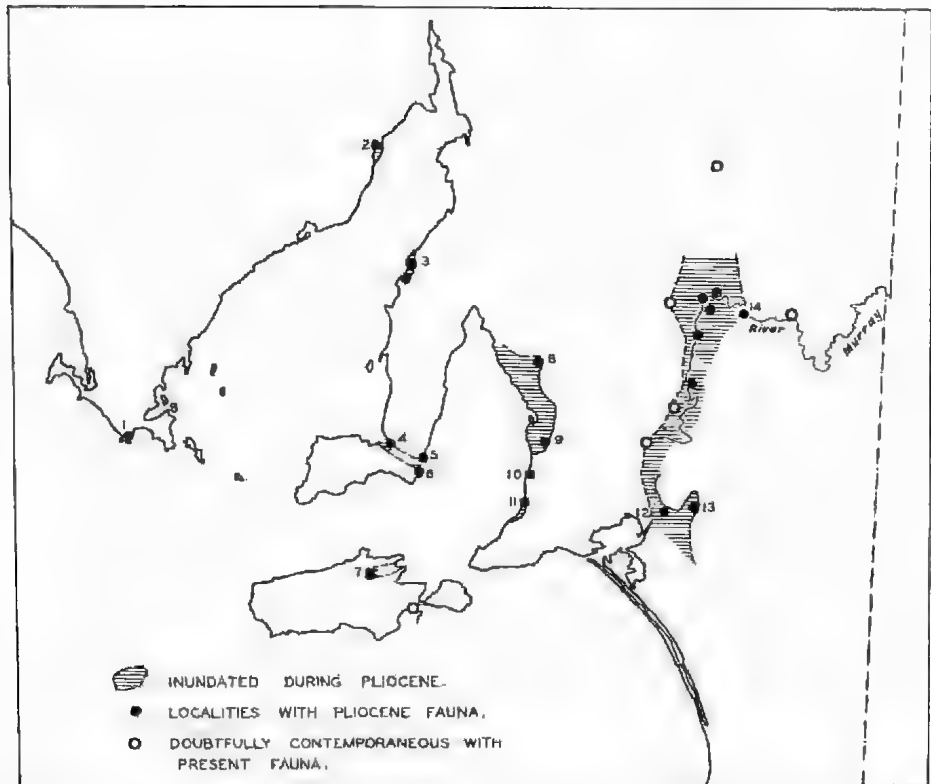


Fig. 1.—1. Fishery Bay; 2. Hd. Poynton; 3. Wallaroo; 4. Hd. Moorowie; 5. Giles Point; 6. Edithburg; 7. Hd. Menzies; 8. Redbanks; 9. Adelaide; 10. Hallett Cove; 11. Aldinga Bay; 12. Tailem Bend; 13. Moorlands; 14. Waikerie.

On *Yorke Peninsula*, Pliocene sandy limestones outcropping on the coast at *Edithburg* and entered in wells west of *Edithburg*, were described by *Basedow* (1901) and correlated with other Pliocene occurrences then regarded as of Miocene age. From the *Edithburg* material *Dr. Basedow* described four molluscan species including *Meretrix sphericula* and *Campanile triseriale*. *Basedow's* types and also the type material of *Tellina basedowi*, which according to *Basedow* (1901, p. 148) was deposited in the Museum of the University of *Adelaide*, have disappeared.

Recently, *Mr. E. J. Carnichael*, of *Yorketown*, has collected assiduously from the Pliocene on his property on *Section 140*, *Hundred of Moorowie*, where the limestone is burned for lime and underground water is obtained at shallow

depth at the base of the formation where it rests on Permian till. Mr. Carmichael's interest has greatly helped in replacing some of the Basedow types and in identifying the extent of the Pliocene in southern Yorke Peninsula.

At Edithburg itself 3 feet of Pliocene sandy limestone covered by 15 feet of kunkar is exposed at Point de Mole at the foot of the steps leading to the old bathing pool. Limestone blocks with abundant *Chlamys antiaustralis* and *Spondylus spondyloides* are strewn at high tide level. From this locality the neotype of *Cardita dennanti* was collected by Mr. Carmichael.

Two miles north of Coobowie at Giles Point, Section 319, Hundred of Melville, a three-foot oyster bed in sandstone is exposed above high tide level at the base of low cliffs 27 feet high. *Tellina basedowi* was re-collected from this exposure. Associated molluscan species are *Ostrea arenicola* and *Chlamys* (*Chlamys*) *antiaustralis*; the foraminifera include *Gribovalimmina polystoma*, *Triloculina trigonula*, *Discorbis dimidiatus*, *Elphidium adelaidense*, *E. rotatum*, "*Rotalia*" *beccarii*, and *Marginopora vertebralis*. The oyster bed is overlain by 22 feet of mottled clayey sandstone with a gravel bed at the base. This is usually considered though not proven to be of Pleistocene age.

From the wall 20 feet below the surface of a well on Section 200, Hundred of Melville, 1½ miles west of Edithburg, A. A. Gibson recently collected a sample of sandy limestone with *Chlamys antiaustralis* and *Chlamys* (*Equichlamys*) *palmipes*. This appears to be the well described by Basedow (1901, pp. 146-7).

No Pliocene has been observed north of Giles Point on the eastern side of Yorke Peninsula although some marginal limestones near Kulpara and Clinton lithologically resemble the characteristically sandy limestones of the Pliocene. The limestones at Kulpara and Clinton, however, carry *Austrotrillina howchini* and locally *Lovenia* and *Monostychia*; they are of Lower Miocene age.

On the western side of the Peninsula two exposures are known near Wallaroo, one at Point Hughes 1 mile west-south-west and a second 2 miles north of the town on Section 925, Hundred of Wallaroo, where Pliocene limestone with abundant molluscan moulds and casts was formerly quarried for flux for the smelters. The fauna, identified from latex casts, includes abundant rather small moulds of *Anodontia sphericula* and *Diastoma provisi*, with *Cucullaea*.

An interesting exposure of the Pliocene occurs on Kangaroo Island. Limestone boulders collected by E. P. O'Driscoll on Section 268, Hundred of Menzies, 11 miles west of Kingscote, carry abundant *Chlamys antiaustralis* in association with *Ostrea*, mostly juveniles, ? *Cardita* sp., *Barbatia* sp., *Cucullaea* sp., *Chlamys* (*Equichlamys*) *consobrina* and *Diastoma provisi*. Although no basalt was actually seen by Mr. O'Driscoll during his short visit to the locality, the limestone has been baked by the basalt which occurs to the west of Kingscote. The fauna is consequently poorly preserved, mainly as casts, moulds, and hardened shells in reddish and grey limestone.

Along the eastern coast of Gulf St. Vincent the Pliocene occurs discontinuously from Aldinga Bay to Adelaide, and the exposures at Aldinga, Hallett Cove and Adelaide have been described by many authors. The sequence in the Dry Creek Sands of the Adelaide Plains Basin is, however, understood only in general terms at present; only one of the molluscan faunas has been described (Ludbrook, 1954-8) and no zoning of the foraminifera has been undertaken.

An exposure of Tertiary beds at Redbanks on the River Light was described by Howchin (1912) and correlated with rocks of Older Tertiary ("Eocene") age elsewhere in South Australia. Some anachronous features of the molluscan species collected from this locality led to the recognition (Ludbrook, 1957, p. 17) of a very thin remnant of Pliocene calcareous sandstone overlying Miocene limestone (Howchin's Eocene).



The general features of the occurrence have been adequately described by Howchin. The Tertiary beds consist of from 12 to 15 feet of hard fossiliferous yellow limestone (calcarene), gritty near the base, carrying the echinoids *Lovenia "forbesi" T. Woods*, *Fibularia gregata*, and the pelecypods *Lentipeecten* sp. and *Eotrigonia semiundulata*. The associated microfauna contains *Amphistegina lessonii*, *Calcarina verriculata*, *Notorotalia howchini* and species of *Gaudryina*, *Dorothyia*, *Nonion*, *Cibicides*, and *Cassidulina*. An echinoid band occurs near the top of the limestone, with abundant *Lovenia*, *Monostychia*, *Fibularia* and *Lentipeecten*, together with *Eotrigonia semiundulata* and *Placotrochus*. Erosion has considerably obscured the contact between the top of the echinoid band and the overlying thin remnant of leached white calcareous sandstone with chalky remains of *Glycymeris convexa*. Where it is best exposed under Pleistocene mottled clays, the sandstone rests upon poorly fossiliferous Miocene calcarenite with echinoid spines, sponge spicules, and miliolid foraminifera; elsewhere it may be represented by a coarse grit resting on the echinoid band of the limestone. Howchin (p. 17) noted the rich fossil content of this "thin siliceous layer". It is obvious from the megafossil assemblage that this is not a bed of the underlying Miocene, but a remnant of the Pliocene Dry Creek Sands encountered in borings in the Adelaide Plains Basin.

One small, loose boulder from the echinoid band of the Miocene carries, vertical to the bedding, a mould of the boring mollusc *Pholus* on the infilling of a tube bored into the limestone. An irregular junction between limestone and grit is also visible on the same boulder.

The Redbanks exposure probably represents the north-eastern margin of the Pliocene sea in this part of the St. Vincent Basin. Although the total exposure is only about 8 feet long and 1 foot thick, the following molluscan species, some of which are restricted to the Pliocene, have been identified: *Nuculana verconis*, *Glycymeris convexa*, *Cucullaea* sp., *Chlamys antiaustralis*, *Cardita compta*, *Miltha hora*, *Notocallista (Striacallista)* sp., *Dentalium lotesuleatum*, *Turritella acricula adalaidensis*, *Diastoma provisi*, *Theridium torri*, *Polinices substolida*, *Conus (Floresconus) adalaidae*. "*Rotalia*" *beccarii* is associated with this assemblage.

Overlying the Tertiary marine beds are about 40 feet of Pleistocene mottled, mainly red, clays and loam.

At *Tailem Bend* the low cliffs forming the eastern bank of the Murray River are composed of fine calcareous loosely coherent sandstone with abundant *Marginopora vertebralis* visible on weathered surfaces. In this area the Miocene has been partially or wholly removed by erosion and Pliocene sands rest directly on grey limestone of the Ettrick Formation. 2½ miles south of Tailem Bend on the stock route adjacent to Section 321, Hundred of Seymour, well preserved mollusca occur in a bed of *Ostrea arenicola* 25 feet down the low cliffs. The splendid specimen of *Spondylus spondylioides* (Pl. 2, Fig. 1) was collected at this locality with *Chlamys (C.) antiaustralis*, *Chlamys (Equichlamys) palmipes*, and *Miltha hora*.

The associated microfauna is similar to that of the Dry Creek Sands.

The sample taken on the eastern bank at Jervois punt contains a shallow water foraminiferal assemblage with *Marginopora vertebralis* and "*Rotalia*" *beccarii* in abundance, in association with *Trochammina inflata*, *Clavulina multiuretata*, *Cribrobulimina polystoma*, *Quinqueloculina costata*, *Triloculina trigonula*, *T. tricarinata*, *Peneroplis pertusus*, *Discorbis dimidiatus*, *Rotorbinella cycloclypeus*. The foraminifera of the oyster bed with *Spondylus*, 2½ miles south of Tailem Bend, include "*Rotalia*" *beccarii* with *Quinqueloculina costata*, *Q. polygona*, *Triloculina tricarinata*, *Guttulina irregularis*, *G. problema*, *G. regina*, *Sigmoidella elegantissima*, *S. kagacensis*, *Discorbis dimidiatus*, *Rotorbinella cyclo-*

*clypeus*, *Planulinoides biconcava*, *Planorbulina mediterraneensis*, *Elphidium adelaidense*, *E. rotatum*, *E. macellum*, *E. advenum*.

The Pliocene at Moorlands has been described by McGarry (1953, p. 87). Five species of mollusca occurring in this locality were recorded by Mawson and Chapman (1922, p. 136). Thin, highly fossiliferous sandy and gritty limestone with large slate pebbles overlies hedrock on Section 6, Hundred of Sherlock, on the roadway where it is thinly covered with kunkar, and to the south of the roadway. *Anodontia sphericula* is abundant, in association with *Macoma basedowi*, *Chlamys* (*Equichlamys*) *consobrina*, *Diastoma provisi*, *Barnea tiara*, *Anapella variabilis*, and doubtfully identified *Antigona cognata*.

The distribution of the fauna at these localities is tabulated below.

The sandy limestone quarried at Waikerie as a building freestone also contains *Anodontia sphericula* and *Diastoma provisi* with moulds of *Polinices* and *Mytilus*.

DISTRIBUTION TABLE

	Moorlands	Tailm Bend	Aldinga Bay	Hallett Cove	Adelaide Plains Basin	Kangaroo Island	Edinburgh	Wallaroo	Eyre Peninsula
<i>Cucullaea</i> sp.	x	x	x	x	x	x		x	x
<i>Glycymeris convexa</i>	x	x			x				
<i>Ostrea arenicola</i>		x	0	x	x	cf.	x		
<i>Chlamys antiaustralis</i>	x		0	x	x		x		x
<i>Chlamys</i> ( <i>Equichlamys</i> ) <i>consobrina</i>	x		0	x	x	cf.			
<i>Chlamys</i> ( <i>Equichlamys</i> ) <i>palmipes</i>	x		0	x	x	cf.			
<i>Chlamys</i> ( <i>Equichlamys</i> ) <i>subbifrons</i>			x		0				
<i>Spondylus spondylioides</i>		x	0	x	x				
<i>Glans denunti</i>							0		
<i>Anodontia sphericula</i>	x		x	x	x		0	x	x
<i>Antigona cognata</i>	x								
<i>Dosinia</i> ( <i>Phacosoma</i> ) <i>edithburgensis</i>							0		
<i>Luciolina aldingae</i>			0						
<i>Macoma basedowi</i>	x						0		
<i>Anapella variabilis</i>	x		0		x				
<i>Diastoma provisi</i>	x		x	x	0	x		x	x
<i>Campunila triseriale</i>			x	x	x		0		

0 Type locality

x Occurrence noted.

## SYSTEMATIC DESCRIPTIONS

## Family PECTINIDAE

## Genus CHLAMYS Röding, 1798

## Subgenus CHLAMYS s. str.

*Chlamys* (*Chlamys*) *antiaustralis* (Tate)

*Synonymy*: Ludbrook, 1955, p. 30.

*Observations*—The species was well figured by Gatliff and Singleton (1930, pl. 2, fig. 3; pl. 3, figs. 6, 7; pl. 4, fig. 10). It occurs commonly in calcareous sandstones carrying the present fauna.

Subgenus *EQUICHLAMYS* Iredale, 1929Type species (n.d.) *Pecten bifrons* LamarckGroup of *Chlamys* (*Equichlamys*) *bifrons* (Lamarck)

Three species described by Tate, *Pecten consobrinus*, *P. subbifrons* and *P. palmipes*, are each morphologically close to variants of the living *Chlamys* (*Equichlamys*) *bifrons*, the type of which is in the Lamarck Collection in the Museum of Natural History, Geneva. These either represent allopatric populations of a single Pliocene species or are Pliocene subspecies of a single polytypic species of which *bifrons* is the living South Australian representative. The amount of material available is, however, too limited for satisfactory comparative study.

*Chlamys* (*Equichlamys*) *subbifrons* (Tate)

pl. 1, fig. 1

*Pecten subbifrons* Tate, 1882, p. 44; 1886, p. 104, pl. 3, fig. 2.

**Diagnosis**—A rather small *Equichlamys* with 12 square-cut bifid ribs equal to the interspaces, cut into riblets in the early stages by a median groove and into 4 or 5 riblets by dichotomous grooves towards the ventral margin. Main interspaces and rib grooves shagreened.

**Description**—The holotype figured by Tate is a juvenile right valve, narrower than the adult. Shell of small to medium size, weakly inflated, height (in the juvenile) greater than the length, anterior-dorsal and posterior-dorsal margin slightly concave, ears large, unequal, posterior ear triangular, with 5 rays with shagreen interspaces; anterior ear larger, upper margin directed slightly upwards, lower margin with a broad but not very deep byssal notch, 6 rays, the upper bifid and much broader than the rest which are divided by one or two grooves, interspaces shagreen.

Main shell sculpture of 12 square-cut ribs, equal to the interspaces. Ribs cut into riblets by one increasing to three square-cut grooves towards the ventral margin. Riblets more or less granular, about 13 granules in 10 mm. Grooves shagreen. Interspaces between main ribs shagreen with a secondary riblet developing by intercalation. Valve margin squarely undulating.

**Dimensions**—Height 30, length 28 mm.

**Type Locality**—Pliocene, "Government House Quarry", Adelaide.

**Location of Holotype**—Tate Museum Collection, University of Adelaide, T 959A.

**Material**—The holotype and 4 paratypes, Adelaide.

**Observations**—The holotype is an ornamented phase of the species. The granules are not always present on the ribs which in juvenile paratype D are shagreened over.

*Chlamys* (*Equichlamys*) *consobrina* (Tate)

pl. 1, fig. 2

*Synonymy*: Ludbrook, 1955, p. 31.

**Diagnosis**—A fairly large *Equichlamys* with about 8 low radial folds. Folds and interspaces covered with narrow radial riblets increasing by intercalation to about 100 in the adult. Interspaces shagreen.

**Description**—Holotype left valve. Shell not fully grown, of medium size, moderately inflated, height equal to length, equilateral, anterior-dorsal and posterior-dorsal margins concave, ears large, unequal, anterior ear triangular, with

10 narrow radial riblets separated by broader shagreened interspaces, posterior ear subtriangular, carrying narrow radial riblets, outer margin broken but apparently very gently sigmoidal, upper margin straight.

Shell with 8 low folds strongest at the middle and almost obsolete anteriorly and posteriorly, both folds and interspaces carrying 3 or 4 flat, slightly granular ribs with shagreened interspaces a little wider than the ribs. Valve margin very gently undulating.

*Dimensions*—Height 67, length 67 mm.

*Type Locality*—Pliocene, Aldinga Bay.

*Location of Holotype*—Tate Museum Collection, University of Adelaide, T 937B.

*Material*—The holotype, one paratype (adult  $85 \times 85$  mm.), 5 topotype fragments; one poorly preserved specimen in limestone, Moorlands.

### *Chlamys (Equichlamys) palmipes* (Tate)

pl. 1, figs. 3-6

*Pecten palmipes* Tate, 1886, p. 105, pl. 5, fig. 4; pl. 7, figs. 4a-4b.

*Diagnosis*—A fairly large *Equichlamys* with 9 strong broad ribs on the right valve and 8 narrow elevated ribs on the left valve, ribs and interspaces covered with flat, square-cut riblets up to 15 on each rib on the right valve. Interspaces shagreened. Height greater than length. Dorsal margins conspicuously concave.

*Description*—Lectotype. Shell fairly large, roundly triangular, inequilateral, slightly inequivalve, higher than long, anterior-dorsal margin shorter than posterior-dorsal, but both relatively short, concave, ventral margin strongly convex. Ears large, unequal.

Right valve with 9 strong broad subrectangular ribs with U-shaped interspaces. The ribs in the median part of the shell are straight and radial, but both anteriorly and posteriorly they become increasingly concave. The two bordering the dorsal margins are separated from the adjacent ribs by a narrow interspace, which varies in intensity in individual specimens. It seems, therefore, a matter of individual preference as to whether the valve is regarded as having 7 (Tate, 1886) or 9 ribs. Ribs broadening and flattening ventrally. Interspaces shagreened. Ears unequal. Posterior ear triangular, outer margin slightly inclined to the vertical, with 11 radiating riblets grooved towards the umbo. Anterior larger, upper margin directed slightly upwards, outer margin convex, lower margin with a broad shallow byssal notch.

Left valve rather flattened in the umbonal region, anterior dorsal margin shorter than posterior, concave; posterior-dorsal margin concave; ventral margin roundly convex, profile narrowly undulating. Valve with 8 narrow inverted U-shaped ribs with deep interspaces twice as wide as ribs which widen and flatten ventrally. Ribs and interspaces carrying riblets developing by intercalation from about 3 per rib in the middle of the shell to about 7 at the ventral margin. Interspaces between ribs and riblets shagreened. Ears unequal. Anterior larger than posterior, triangular with 5 primary and radiating riblets with a secondary riblet developing in each interspace; posterior subtriangular, upper margin sloping downwards, outer margin meeting it at  $115^\circ$ .

*Dimensions*—Height 75, length 72, inflation (both valves) 27 mm.

*Type Locality*—Pliocene, Edithburg.

*Location of Lectotype*—Tate Museum Collection, University of Adelaide, T 932A.

**Material**—The lectotype and paratype T 932B, both complete specimens except for damage to posterior-ventral margin of holotype. One complete juvenile with smooth ribs and 4 valves, Tailern Bend; 1 valve in limestone with *Chlamys antiaustralis*, well at 20 feet, Section 200, Hundred of Melville, 1½ miles west of Edithburg.

**Observations**—Tate's description was based on two specimens, both of which were figured. The larger T 932A (figured 1886, pl. 7, figs. 4a-4b), of which Tate gave the approximate dimensions, is chosen as lectotype.

#### Family SPONDYLIDAE

Genus SPONDYLUS Linné, 1758

*Spondylus spondyloides* (Tate)

pl. 2, fig. 1

*Synonymy*: Ludbrook, 1955, p. 34.

The magnificent specimen (pl. 2, fig. 1) Tate Mus. Coll. F 15470, with both valves intact was collected south of Tailern Bend in calcareous partially coherent sandstone.

#### Family CARDITIDAE

Genus GLANS Megerle, 1811

Type species (monotypy) *Glans trapezia* = *Venus trapezia* Linné

*Glans dennanti* (Tate and Basedow)

pl. 2, figs. 2, 3

*Cardita dennanti* Tate and Basedow, 1902, p. 132, pl. 2, fig. 4.

**Diagnosis**—A subtrapezoidal inflated *Glans* with about 20 rather broad nodulose ribs.

**Description**—Neotype. A single right valve of moderate size, broadly subtrapezoidal in outline, strongly inflated, solid. Umbo prominent, inflated, strongly prosogyrous, situated at one-third from the anterior margin. Lunule small, cordate, escutcheon well defined. Anterior-dorsal margin almost straight, anterior margin arcuate, posterior-dorsal margin gently convex, posterior margin obscured by matrix, ventral margin gently convex. Sculpture of about 20 broad nodulose ribs wider than the interspaces. Ribs and interspaces crossed by irregular growth lines. Inner valve margin coarsely crenulate. Hinge fairly broad, damaged, but showing a strong, high, prominent, triangular 3b.

**Dimensions**—Height 23, length 24, inflation (one valve), 10 mm.

**Location of Neotype**—S.A. Museum No. P.12657.

**Type Locality**—De Mole Point, Edithburg.

**Material**—The neotype only. Although the dimensions are greater, the specimen collected by Mr. E. J. Carmichael from Point de Mole is so like the figure of the holotype that there can be no hesitation in selecting it as the neotype.

#### Family LUCINIDAE

Genus ANODONTIA Link, 1807

*Anodontia* Link, 1807, p. 156.

(*Loripinus* Monterosato, 1883, p. 91).

(*Eophysema* Stewart, 1930, pp. 37, 186; non *Anodontia* Stewart, 1930, p. 179.

*Anodontia* Link, 1807, Eames, 1951a.

Type species (monotypy) *Anodontia alba* Link = "*Venus*" *edentula* Linné

*Anodontia sphericula* (Basedow)

pl. 3, figs. 1, 2, 3; pl. 5, figs. 1, 4

*Meretrix sphericula* Basedow, 1902, p. 131, pl. 2, fig. 2; Howchin, 1935, pp. 84, 89; 1936, pp. 7, 14.

**Diagnosis**—A large globose *Anodontia*, thin shelled, sculptured with irregular growth lines about 1 mm. apart, with very fine secondary threads between. Hinge edentulous, anterior adductor well within pallial line, rectangular, about 20 mm.  $\times$  6 mm., posterior adductor subtriangular, about 10  $\times$  10  $\times$  15 mm.

**Description**—Shell large, thin, transversely orbicular, strongly inflated, sculptured with fine distinct accremental ridges about 1 mm. apart in the middle of the shell with fine secondary irregular microscopic threads between them and very fine short microscopic radial striae discernible on some portions of the adult shell.

Anterior area narrow, marked externally by a slight interruption of the concentric ridges which fold over on a slight umbo-ventral furrow. Posterior area narrow, less conspicuous than anterior area but similarly separated from the main part of the shell by a slight depression from the umbo to the posterior ventral edge.

Umbo small, smooth, sharp, not prominent, prosogyrous, situated anteriorly in the ratio 26:37. Anterior-dorsal margin almost straight, directed slightly upwards, meeting the anterior end in a broad curve. Posterior-dorsal margin relatively long and gently convex; gently descendent towards the posterior, meeting the posterior margin at a rounded obtuse angle. Ventral margin strongly convex.

Hinge edentulous, ligament long, narrow, bounded by a ridge. Anterior adductor long, rectangular, within the pallial line and diverging from it at an angle of about 20 degrees over three-quarters of its length, 21 mm. long, 6 mm. wide in the Cowandilla hypotype. Posterior adductor subtriangular, pointed dorsally with straight sides each 10 mm. long, ventral side convex towards the ventral margin, about 15 mm. long. There is a conspicuous umbo-ventral ridge bordering the inner side of the posterior adductor and a less conspicuous furrow extending from the inner margin of the anterior adductor in a broad sigmoid curve towards the posterior end of the hinge at the top of the pedal retractor. Pallial line simple, area outside pallial line smooth, inside granular.

**Dimensions**—Neotype height 72, length 82, inflation (cast, both valves, 47). Hypotype, Cowandilla Bore, height 57, length 63, inflation (both valves) 31 mm.

**Type Locality**—Edithburg.

**Location of Types**—South Australian Museum, Neotype P 12658; Hypotype, Moorowie, P 12659; Hypotype, Cowandilla Bore, 470-485 feet, Tate Mus. Coll., University of Adelaide, F 15471.

**Material**—The neotype and 2 topotypes collected from Edithburg in the Howchin Collection, S.A. Museum. 1 specimen 305 from Giles Point in collection of E. J. Carmichael, 9 specimens, Hundred Moorowie, Section 140, E. J. Carmichael Collection. 4 casts Wallaroo, 2 casts Aldinga, 2 casts Moorlands, 3 casts Fishery Bay; 17 fragments Cowandilla Bore, 1 valve Bore, Hundred of Munno Para, Section 4251, S.A. Mines Department Collection; Hypotype F 15471 placed in Tate Collection.

**Observations**—The whereabouts of the holotype are not known, but there has been no difficulty in finding specimens to replace it. The hypotype from Hundred of Moorowie is a large example, partly decorticated but with a fair amount of the outer shell layer still remaining. 22 adult specimens were mea-



sured, the average dimensions of which were height 64 mm., length 71 mm., inflation 43 mm., umbo-anterior 29 mm., umbo-posterior 42 mm., ratio height: length 0.901, ratio umbo-posterior: umbo-anterior 1.44. In the adult the height: length ratio varies from 0.90 to 0.95, in the juvenile from 0.80 to 0.95; in the adult the position of the umbo is more central in the ratio UP:UA is 1.23:1.62; in the juvenile the ratio UP:UA is 1.00:1.61.

Large globular casts of this species are very common in the limestones. With the removal of the shells by solution, the casts readily weather out. Casts appear to be similar to those of *Anodontia pharaonis* (Bellardi) occurring in the Eocene from Spain to India (Cox, 1936, p. 32; Fames, 1951b, pp. 390-2). *A. philippiana* (Reeve) from North Queensland is a close living relative. The species, or one very close to it, also occurs in the Pleistocene sandy limestones of the Eyre (Roe) Plain south of the Hampton Scarp in the Eucla Basin.

#### Family DOSINIIDAE

##### Genus DOSINIA Scopoli, 1777

Type species (monotypy) *Chama dosin* Adanson = *Venus concentrica* Born

##### Subgenus PHACOSOMA Jukes-Brown, 1912

Type species (o.d.) *Artemis japonica* Reeve

*Dosinia* (*Phacosoma*) *edithburgensis* sp. nov.

pl 3, fig. 4

*Dosinia grayii* Zittel, Basedow, 1901, p. 147 (non Zittel).

**Diagnosis**—A fairly large suborbicular *Phacosoma*, moderately thin-shelled, sculptured with fine, erect ridges about 2 mm. apart, with about 8 fine striae on the interspaces and ridges. Pallial sinus deep, triangular, with apex about the middle of the median umbo-ventral line.

**Description (Holotype)**—Shell large, suborbicular, umbos inflated, prominent strongly prosogyrous, lunule deeply impressed, somewhat sagittate. Escutcheon narrow, deep. Sculpture on adult portion of shell consists of narrow concentric ridges about 2 mm. apart with finely striated interspaces.

Hinge plate moderately narrow, partly obscured by matrix. Hinge of right valve with long, narrow, high grooved posterior cardinal, a prominent bevelled median cardinal and a narrowly triangular entire anterior cardinal. Anterior lateral portion of hinge obscured. Pallial sinus not visible in holotype.

**Dimensions of Holotype**—Height 66, length 65, inflation (both valves) approximately 34 mm.

**Paratype**—Internal cast with a good deal of the original shell. Part of the pallial sinus visible, broadly triangular, deep, inclined, with apex directed towards the anterior end of the hinge at the probable position of the anterior adductor; apex at about the middle of the median umbo-ventral line.

**Type Locality**—Edithburg, Pliocene.

**Location of Types**—Tate Museum Collection, University of Adelaide, Holotype F 15467, Paratype F 15468.

**Observations**—This is one of the shells recorded by Tate as *Dosinia grayii* Zittel. It is a larger shell with only a superficial resemblance to *D. (Kereia) grayi* Zittel from New Zealand and has not so far been collected from any other locality than Edithburg. Two specimens in the Tate Collection from "Miocene, Gippsland Lakes"—probably Jemmy's Point Formation (Pliocene)—appear to be long to *Kereia*, although the hinge is obscured. They are somewhat similar



to but not conspecific with *greyi*. Marwick (1926, p. 570) has noted that the Japanese subgenus *Phacosoma* is not known to occur in New Zealand before the Lower Pliocene.

Family TELLINIDAE

Genus MACOMA Leach, 1819

Type species (monotypy) *Macoma tenera* Leach = *Tellina calcarea* Linné

*Macoma basedowi* (Tate)

pl. 4, figs. 3, 4

*Tellina basedowi* Tate in Basedow, 1901, p. 148, pl. 3.

**Diagnosis**—A fairly large suborbicular-triangular *Macoma* with slightly irregular concentric lamellae up to about 1 mm. apart and faint radial striae visible in oblique light.

**Description**—Interior cast and portion of right valve selected as neotype. Shell of moderately large size, suborbicular-triangular, probably fairly solid, sub-equilateral, gently inflated. Umbos probably small, antemedian. Anterior-dorsal margin nearly straight, gently sloping; posterior-dorsal margin longer, gently arcuate, more steeply sloping. Anterior margin roundly arcuate, posterior margin more narrowly arcuate. Ventral margin roundly convex.

Sculpture of sharp concentric lamellae widely spaced and generally about 6 in 4 mm., the interspaces crossed by numerous faint radial striae. Pallial sinus widely rhombic, apex at about the posterior one-third.

**Dimensions** (internal cast)—Height 32, length 36, inflation 15 mm.

**Type Locality**—Giles Point, near Edithburg.

**Location of Neotype**—Tate Museum Collection, University of Adelaide, F 15469.

**Material**—The neotype and 2 topotypes, Giles Point, 2 miles north of Coobowie; 4 specimens Moorlands, Section 6, Hundred of Sherlock.

**Observations**—The species appears to have features in common with *Tellina piratica* Hedley, 1918, collected by Basedow in the Buccaneer Archipelago. The pallial sinus is similar in shape to that of *piratica*.

Genus LACIOLINA Iredale, 1937

Type species (o.d.) *Tellina quoyi* Sowerby

*Laciolina aldingae* sp. nov.

pl. 2, fig. 4

*Tellina lata* Tate, 1887, p. 164, non Quoy and Gaimard.

**Diagnosis**—A large *Laciolina* with conspicuous concentric sculpture consisting of crowded striae on the outer layer, the inner layer and shell interior with broad concentric ribs about 2 mm. apart. Anterior margin rounded, posterior-ventral margin rostrate with fairly strong flexure.

**Description**—Shell large, subelliptical-subtriangular, only moderately inflated. Umbos small, submedian. Anterior of shell broken in holotype, posterior dorsal margin apparently straight, fairly steeply descending, posterior end produced, rostrate, strongly flexed, ventral margin convex.

Sculpture on surface layer on undecorticated portion of valve consisting of fine irregular crowded concentric striae about 4 per mm. Decorticated shell with broad rounded concentric ribs about 2 mm. apart on median part of shell. Pallial line only partly visible, pallial sinus not known.

Paratype an internal cast showing anterior margin; anterior-dorsal margin steeply sloping, anterior end narrowly rounded.

*Dimensions*—Holotype: Length (estimated) 125, height 75, inflation 28 mm.

*Material*—The holotype and two paratypes, 1 doubtful topotype.

*Type Locality*—Aldinga Bay, Pliocene.

*Location of Types*—Tate Museum Collection, University of Adelaide, holotype T 1210A, paratypes T 1210B, 1210C.

*Observations*—Tate (1887) referred the Aldinga specimens to the Recent "*Tellina lata* Quoy and Gaimard" on description and figures. A splendid series of the *Tellina lata* Q. and G. group has been generously made available on loan from the Australian Museum; *Laciolina quoyi* (Sowerby) (? = *Tellina lata* Q. and G.) C 15874 Hargraves Collection, from New Caledonia; *Laciolina chloroleuca* (Lamarck) C 15873 Hargraves Collection, New Caledonia; *Laciolina quoyi* ? *attracta* Iredale C 62322, Heron Island, Queensland; *Laciolina quoyi* *attracta* Iredale Paratype C 62323 Lord Howe Island; *Laciolina francesae* Iredale Paratype C 59874 Roy Bell Collection, Norfolk Island. From these it is clear that the Aldinga Pliocene species is distinct both in its dissimilar sculpture and in the strongly rostrate posterior margin. The state of preservation of the fossil renders the generic location a little doubtful. The low, rather narrow pallial sinus of *Laciolina* is not confirmed.

#### Family MACTRIDAE

Genus ANAPELLA Dall, 1895

Type species (o.d.) *Anapa triquetra* Hanley

*Anapella variabilis* (Tate)

pl. 4, figs. 5, 6

*Anapa variabilis* Tate, 1887, p. 172, pl. 17, figs. 5a-5b.

*Anapella variabilis* Tate, Ludbrook, 1955, p. 76 (synonymy).

*Diagnosis*—A small rather tumid subtrigonal *Anapella* with a rather narrow hinge.

*Description*—Holotype, left valve. Shell small for the genus, tumid, subtrigonal, inequilateral, thin but solid, umbo inflated, prosogyrous, anterior margin moderately narrowly arcuate, posterior dorsal margin longer than anterior dorsal margin. Anterior dorsal margin incurved near the umbo. Surface sculpture with fine growth ridges about 1 mm. apart near the umbo but increasing to about 4 per mm. towards the ventral border. Fine striae about 7 per mm. in the interspaces.

Hinge with a deep triangular resilifer. Dorsal margin deeply and narrowly notched under the umbo by the resilium. A grooved, oblique, narrowly triangular anterior cardinal bordering the resilifer with a small secondary denticle overhanging the resilifer at the top of the anterior cardinal. Both anterior and posterior laterals long and thin.

Anterior adductor moderately large, subovate, near the anterior-ventral margin, posterior adductor subovate at the posterior end of the hinge; pallial line simple.

*Dimensions*—Length 17.5, height 13.5, inflation (left valve) 6.5 mm.

*Type Locality*—Blanche Point, Aldinga Bay, Pliocene.

*Location of Types*—Tate Museum Collection, University of Adelaide, Holotype T 1209A, Paratypes T 1209.

**Material**—Holotype and 13 paratypes on Tate's original tablet; external moulds on limestone, identified from latex casts, Moorlands; specimens from Adelaide Plains Basin Government Bore No. 20, Woodville South, 362-380 feet associated with a larger species of *Anapella* (? *pinguis* Crosse and Fischer), and a megafauna distinct from that described by the writer from the Dry Creek Sands.

Class GASTROPODA

Family CERITHIIDAE

Subfamily CAMPANILINAE

Genus CAMPANILE Bayle, 1884

Type species (s.d. Crossman, 1906) *Cerithium giganteum* Lamarck

*Campanile triseriale* Basedow

pl. 5, figs. 2, 3, 4

*Campanile triseriale* Basedow, 1902, p. 130, pl. 2, fig. 1.

**Diagnosis**—A *Campanile* of normal size for the genus, sculptured with three rows of tubercles the adapical row axial, coarse, usually about 4 in 5 mm., separated by interspaces of the same size, median row narrow, set on a narrow cord  $\frac{1}{4}$  mm. wide, about 7 in 5 mm., adapertural row oblique, on a rib about 1 mm. wide, 6 tubercles per mm.

**Description**—Neotype. The neotype has been selected from the Huwchin Collection in the South Australian Museum. It is a broken specimen tightly embedded in limestone with nine adult whorls only the posterior of which is visible externally. The original description and figure given by Basedow are consistent with the neotype, the estimated dimensions of which are height 130 mm., diameter 40 mm.

**Hypotype**. Mould in limestone, north side of Aldinga Bay, south of Blanche Point described from latex cast. Shell large, isostrophic, multispiral, turriculate. Early whorls (about 15) missing, 17 whorls remaining in a height of 90 mm. Whorls narrow, flat regularly sculptured with 3 rows of tubercles, the adapical row broad, one-third width of whorl, with broad tubercles 3 in 5 mm. in the last whorl, separated by approximately equal interspaces, median row of tubercles on a narrow, well-defined cord, about 1 mm. apart, adapertural row bordering the suture, with oblique tubercles about 4 in 5 mm. in the last three whorls.

**Location of Types**—Neotype, South Australian Museum, No. P 12660. Hypotype, South Australian Museum, No. P 12661.

**Type Locality**—Edithburg, Pliocene.

**Observations**—Seven good specimens of the original shells of this species are in the South Australian Museum with the locality label "Bore". The preservation leaves little doubt that the shells are from the Dry Creek Sands of the Adelaide Plains Basin. It is unfortunate that the locality has not been recorded as these are the only well preserved specimens showing the early part of the shell so far obtained; they are also the only record of the species from the Dry Creek Sands.

In the early whorls a narrow somewhat irregular cord occurs between the adapertural row of tubercles and the suture; this cord is gradually engulfed and disappears on later whorls. The aperture is obliquely rhomboid, siphonal canal strongly retroflexed.

**Associated Species**—Associated with the pelecypoda and one gastropod described above are several species the synonymy and descriptions of which have been published previously. These are included in the distribution table.

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## EXPLANATION OF PLATES

## PLATE 1

- Fig. 1.—*Chlamys* (*Equichlamys*) *subbifrons* (Tate). Holotype, T 959A, x 2.  
 Fig. 2.—*Chlamys* (*Equichlamys*) *consobrina* (Tate). Holotype, T 937B, x 0.75.  
 Fig. 3.—*Chlamys* (*Equichlamys*) *palmipes* (Tate). Lectotype, T 932A, left valve, x 0.73.  
 Fig. 4.—*Chlamys* (*Equichlamys*) *palmipes* (Tate). Lectotype, T 932A, right valve, x 0.73.  
 Fig. 5.—*Chlamys* (*Equichlamys*) *palmipes* (Tate). Juvenile, Tailern Bend, left valve, x 2. Mines Dept. Coll.  
 Fig. 6.—*Chlamys* (*Equichlamys*) *palmipes* (Tate). Juvenile, Tailern Bend, right valve, x 2. Mines Dept. Coll.

## PLATE 2

- Fig. 1.—*Spondylus spondyloides* (Tate). F 15470, x 1.  
 Fig. 2.—*Glans dennanti* (Tate and Basedow). Neotype, S.A. Mus. P 12657, x 2.  
 Fig. 3.—*Glans dennanti* (Tate and Basedow). Neotype, S.A. Mus. P 12657, x 2.  
 Fig. 4.—*Lacolina aldingae* Ludbrook, sp. nov. Holotype, T 1210A, x 1.

## PLATE 3

- Fig. 1.—*Anodontia sphericula* (Basedow) Hypotype, F 15471, left valve, x 1.  
 Fig. 2.—*Anodontia sphericula* (Basedow) Hypotype, F 15471, right valve, x 1.  
 Fig. 3.—*Anodontia sphericula* (Basedow) Hypotype, F 15471, exterior, x 1.  
 Fig. 4.—*Dosinia* (*Phacosoma*) *edithburgensis* Ludbrook sp. nov., Holotype, F 15467, x 0.85.  
 Fig. 5.—*Dosinia* (*Phacosoma*) *edithburgensis* Ludbrook sp. nov., Holotype, F 15467, x 0.85.

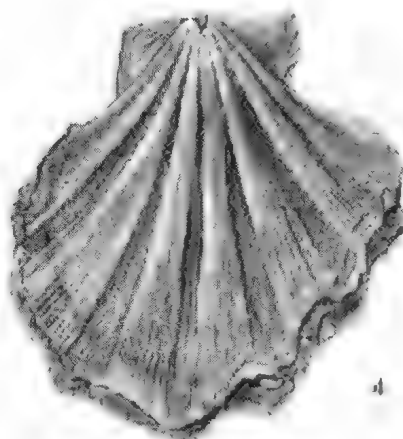
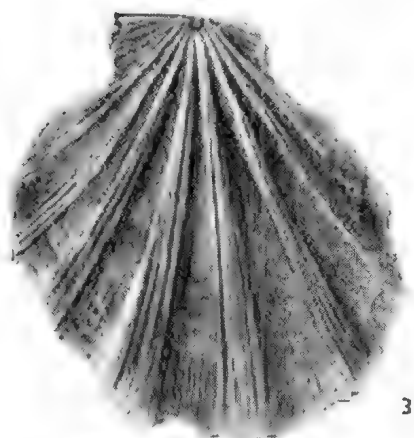
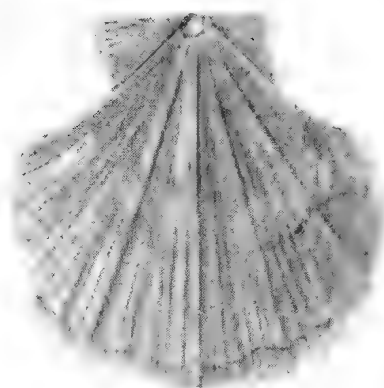
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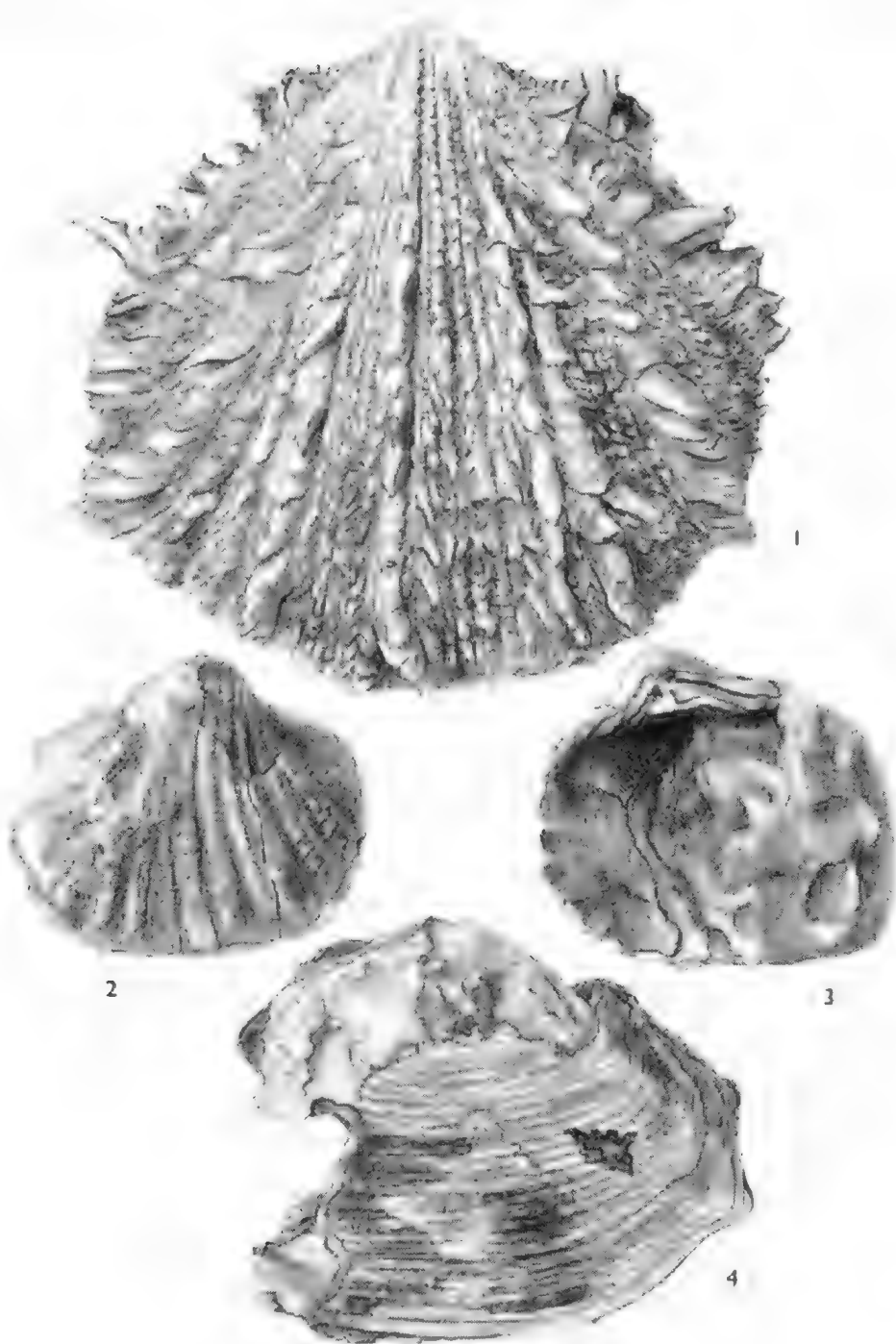
- Fig. 1.—*Ostrea arenicola* Tate. Tailern Bend. S.A. Mines Dept., F 196/58, left valve, x 0.75.  
 Fig. 2.—*Ostrea arenicola* Tate. Tailern Bend. S.A. Mines Dept., F 196/58, right valve, x 0.75.  
 Fig. 3.—*Macoma basedowi* (Tate). Neotype, F 15469, x 1.5.  
 Fig. 4.—*Macoma basedowi* (Tate). Neotype, F 15469, x 1.5.  
 Fig. 5.—*Anapella variabilis* (Tate). Holotype, T 1209A, x 3.7.  
 Fig. 6.—*Anapella variabilis* (Tate). Holotype, T 1209A, x 3.7.

## PLATE 5

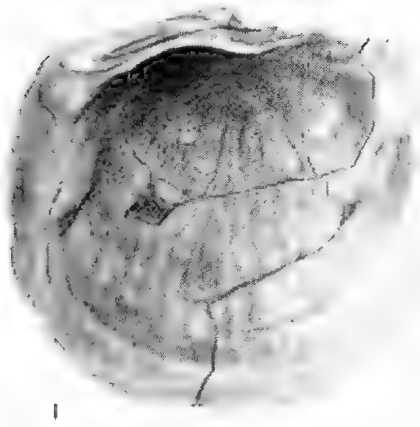
- Fig. 1.—*Anodontia sphericula* (Basedow). Neotype, Edithburg. S.A. Mus., P 12658, x 1.  
 Fig. 2.—*Campanile triseriale* Basedow. Latex cast of hypotype, P 12661, x 1.  
 Fig. 3.—*Campanile triseriale* Basedow. Neotype, Edithburg. S.A. Mus., P 12660, x 1.  
 Fig. 4.—Cast of *Anodontia sphericula* and mould of *Campanile triseriale* hypotype, in limestone, Aldinga Bay. S.A. Mus., P 12661, x 1.

(All photographs by courtesy of S.A. Museum.)

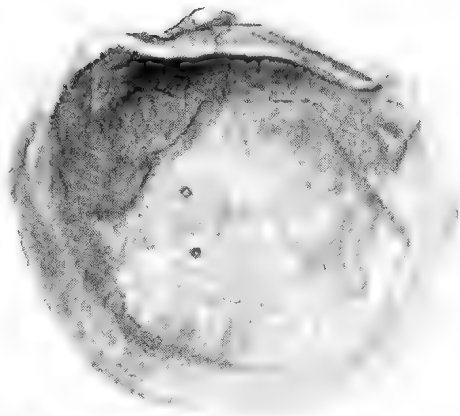




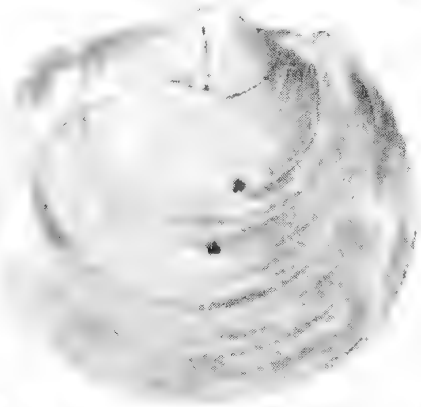




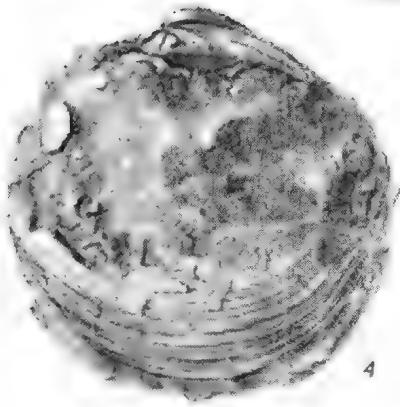
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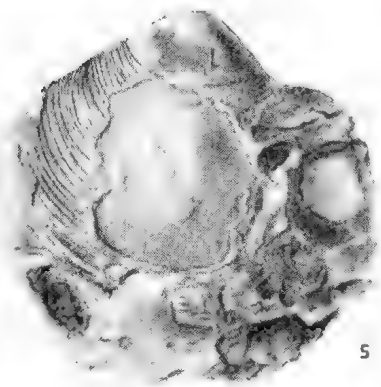
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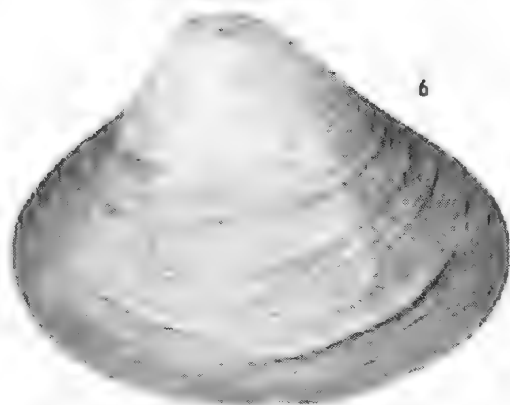
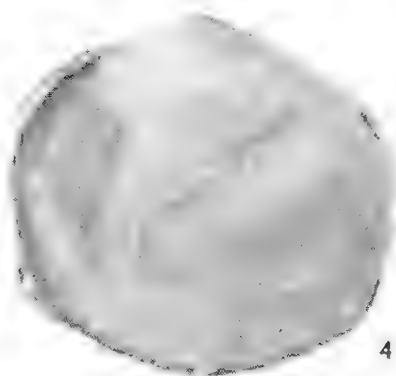
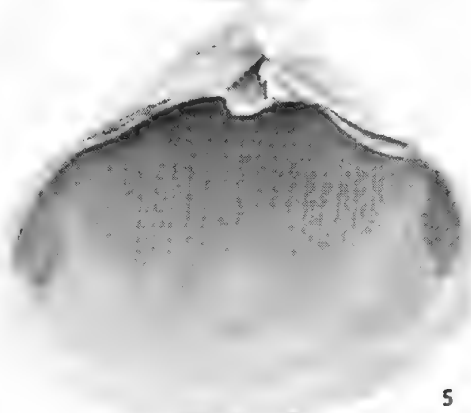
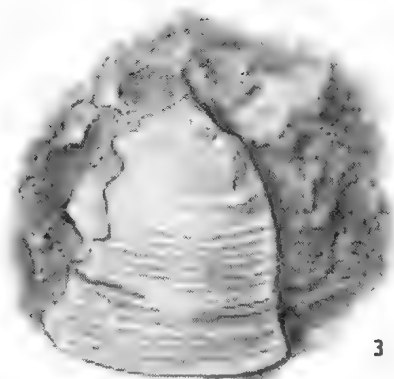
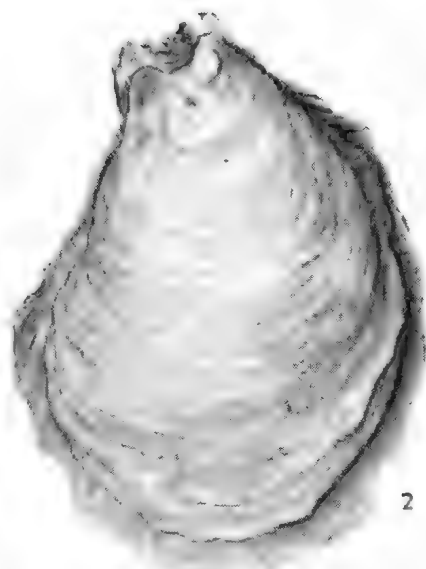
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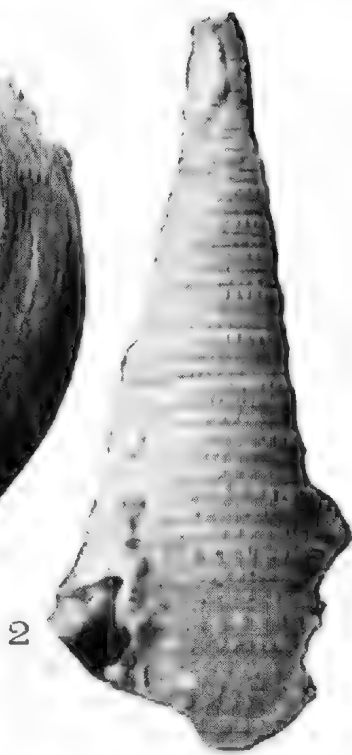
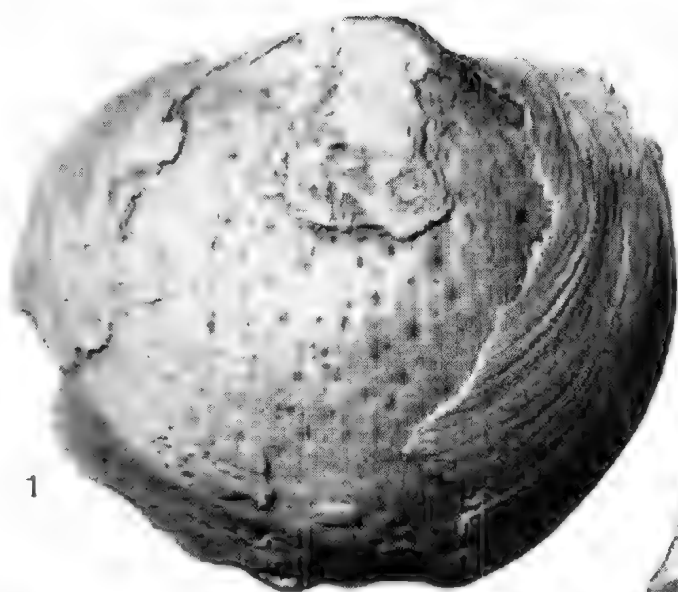


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# **THE CORRELATION BETWEEN SALINITY AND RIVER FLOW IN THE ALICE SPRINGS TOWN WATER SUPPLY**

*BY B. R. JEPHCOTT*

## **Summary**

The results of an investigation into the relationship between recharge of the Alice Springs basin and the salt content of the town water supply are presented.

# THE CORRELATION BETWEEN SALINITY AND RIVER FLOW IN THE ALICE SPRINGS TOWN WATER SUPPLY

by B. R. JEPHICOTT\*

communicated by T. N. LOTMAN

[Read 9 October 1958]

## SUMMARY

The results of an investigation into the relationship between recharge of the Alice Springs basin and the salt content of the town water supply are presented.

## INTRODUCTION

Alice Springs is nestled in the heart of the Macdonnell Ranges and is completely surrounded by hills. The average annual rainfall is of the order of 10 inches and evaporation is about 100 inches. Hence, knowledge and conservation of water supplies is all important.

The water for the town has always been obtained from wells or bores sunk into the porous structure which forms the water-retaining beds underneath the town itself. The basin is recharged by infrequent flowing of the Todd River.

Estimates of the capacity vary from 900,000,000 gallons (Owen, 1954) to 330,000,000 gallons (Jones, 1957), but regardless of this, with a peak summer loading of the order of 3,500,000 gallons per week and a winter loading of about 1,500,000 gallons per week, there is, at the moment, considerable margin for error in estimation of volume since either capacity far exceeds the drain per year.

Pumping, at the time of a survey in 1954, was performed at four major points, namely, Town Wells, Army Wells, Bent Tree Well and Todd River Well. Since then, numerous other town supply bores have been opened and there are many private wells or bores which do not feed into the town mains.

The depths and pumping rates of the town wells and bores used for this investigation are given in Table 1 and their positions are indicated on Fig. 1:

TABLE 1.

Name	Depth	Capacity used.
Town Wells (2)	23'9"	2,000 gallons per hour each.
No. 1 Army Well	25'1"	3,000 gallons per hour
No. 2 Army Well	27'7"	6,000 gallons per hour
Todd River Well	9'2"	8,000 gallons per hour

## PRELIMINARY INVESTIGATIONS

Owen (1954) performed a survey of the Alice Springs basin and found that the most important additions of water to the storage are made from the river when, and shortly after, it flows. Water also enters the basin from the west at

\* Chemist, Animal Industry Branch, N.T. Administration.

the west corner of the town aerodrome, probably a small quantity from the north-west towards the Railway Station and also from the west near the southern boundary of the town aerodrome. These additions are likely to be more saline than the river water and he considered this point should be checked by analyses of water from the bore used by Connellan Airways.

The only early analyses available are those performed by the author in October, 1953.

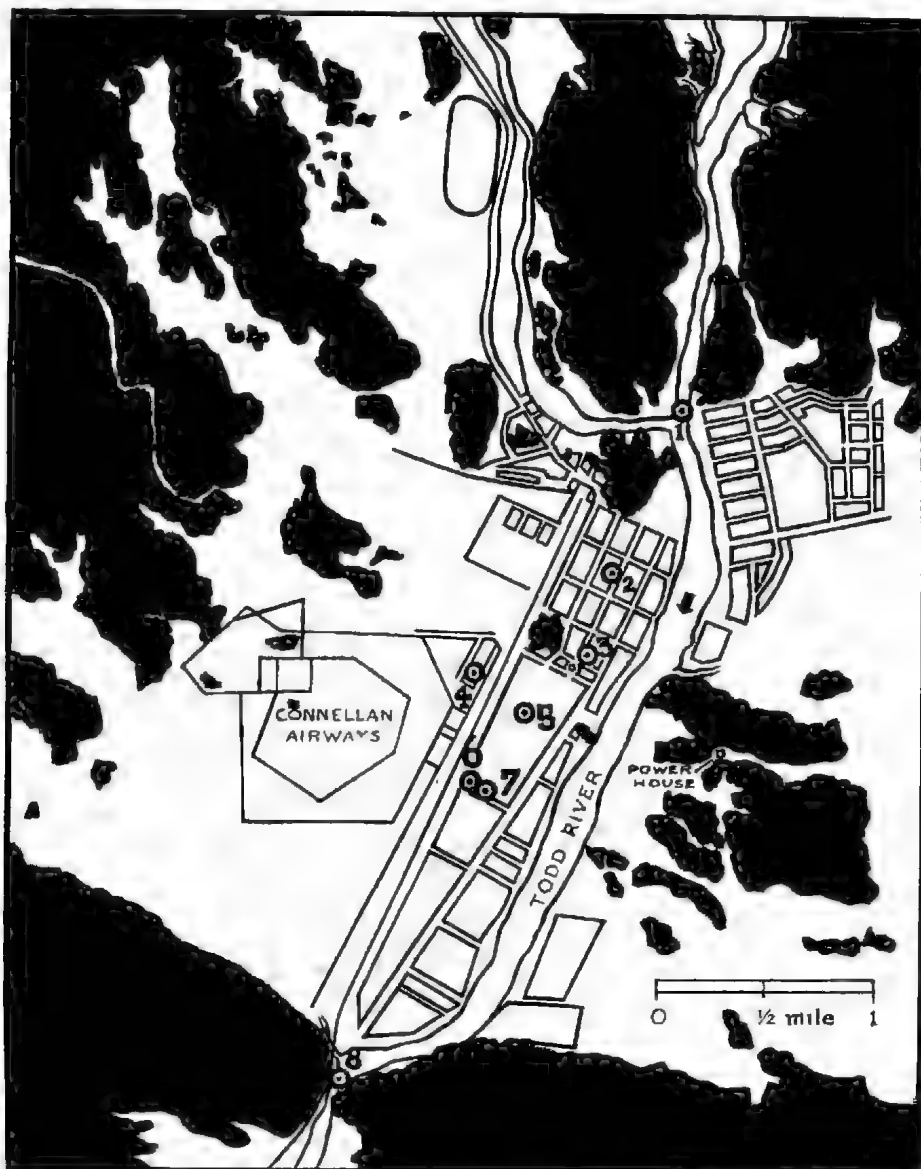


Fig. 1. Map of the Alice Springs area showing the localities of the principal wells supplying water to the town. The dark areas represent stony ranges providing the local watersheds. 1. Todd River Well. 2. A.I.M. Well. 3. Town Wells. 4. Mount Gillen Motel Bore. 5. Bent Tree Well. 6. Army Well No. 1. 7. Army Well No. 2. 8. Heavytree Gap Well.

TABLE 2.

	1	2	3	4
Bicarbonate	165 ppm	110 ppm	213 ppm	311 ppm
Chloride	25	30	70	165
Sulphate	10	10	40	105
Fluoride	0.16	0.08	0.44	0.72
Calcium	24	20	20	35
Magnesium	14	8	16	19
Sodium	30	27	91	198
Silica, Ferric and other oxides	8	4	9	63
Total Salts (parts per million)	276	209	469	897
Total Salts (grains per gallon)	19.5	14.5	32	63

Where: 1. Todd River Bore. 2. Power House Tank. 3. Town Well 6-in. main.  
4. Army Well No. 2.

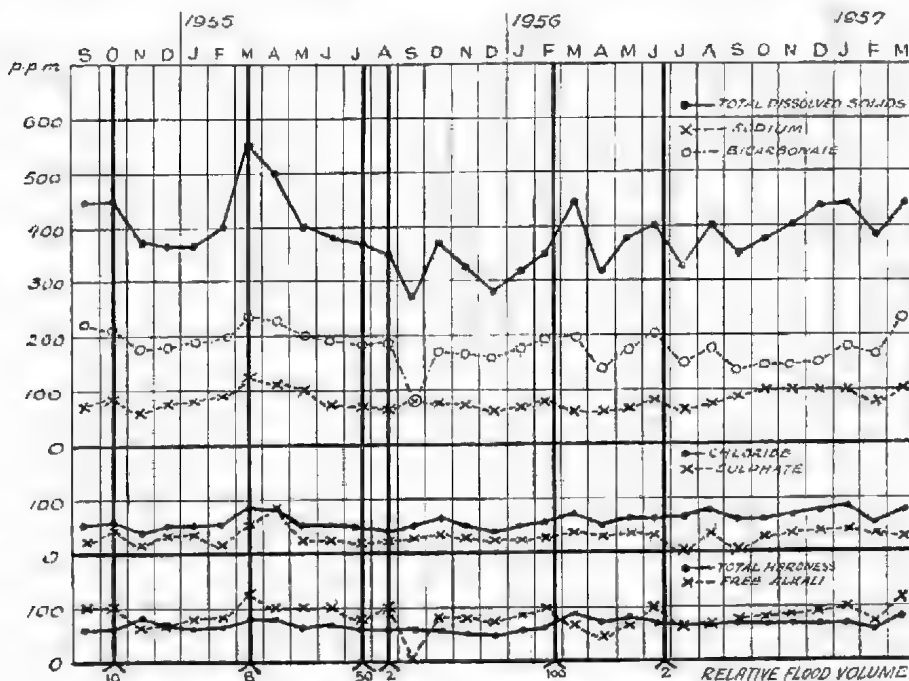


Fig. 2. Composition of monthly samples of water from the Town Wells.

The positions of the sources of samples 1, 2, 3 and 4 are shown on Fig. 1. It is interesting to note the increase in salt content to the south. The above results suggested that the Army Well may mark the southern limit of potable water. These observations indicated that a more detailed study would be important.

#### MAIN INVESTIGATIONS

Monthly water samples from four sites, Town Wells, Nos. 1 and 2 Army Wells and Todd River Well, were collected as from September, 1954, Mt. Gillen Motel from August, 1955, and Australian Inland Mission (Lot 75) from April,



B. R. JEPHCOTT  
MOUNT GILLEN MOTEL

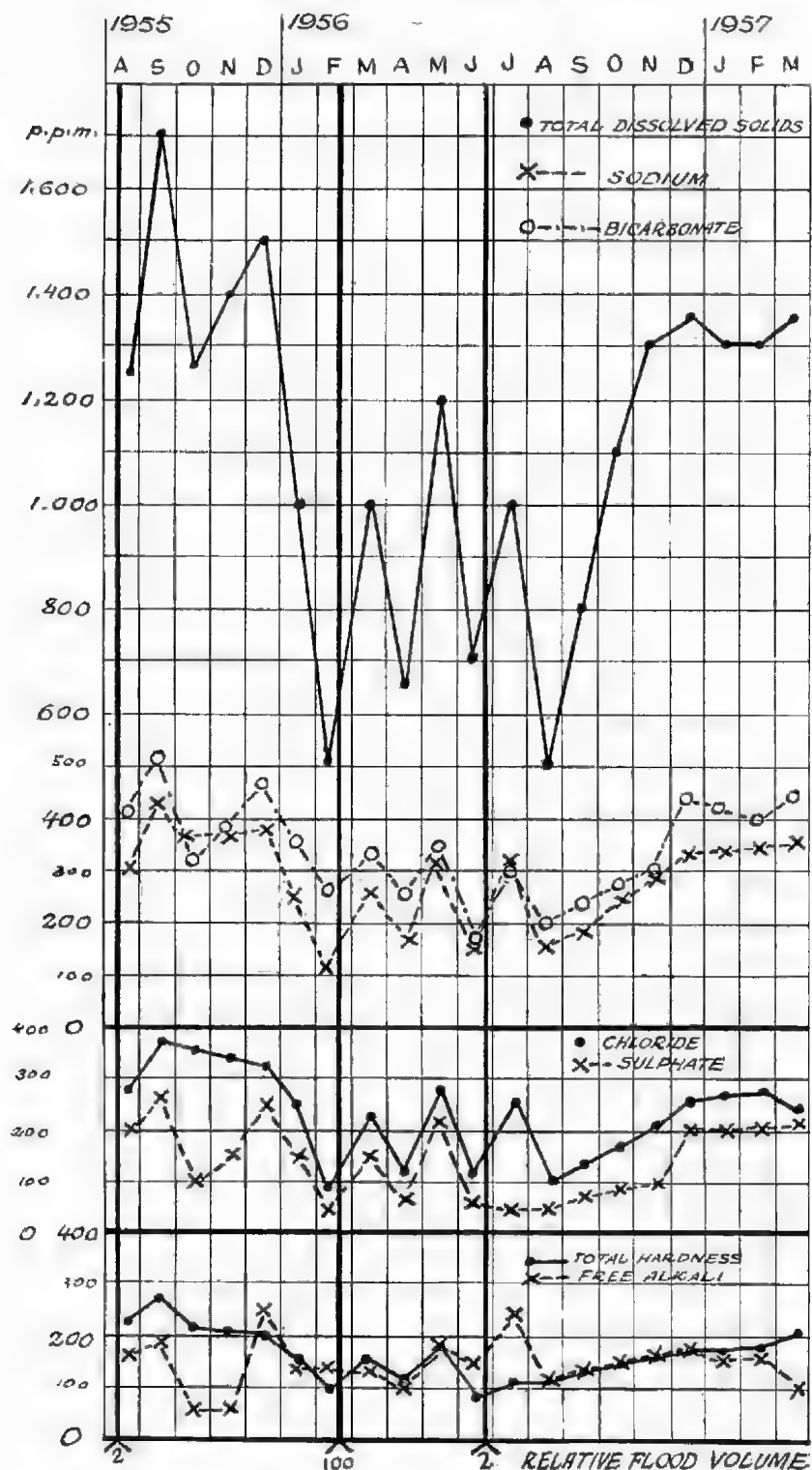


Fig. 3. Composition of monthly samples of water from the Mount Gillen Motel Bore.

1956, until April, 1957. The results were plotted for 14 different factors, but only eight were finally considered of any significance. All these samples were collected as near as possible to the 18th of each month.

The methods used were:—

**Nitrate:** The standard method using Phenoldisulphonic acid (Am. Public Health Assoc., 1955).

### ARMY WELL No 2

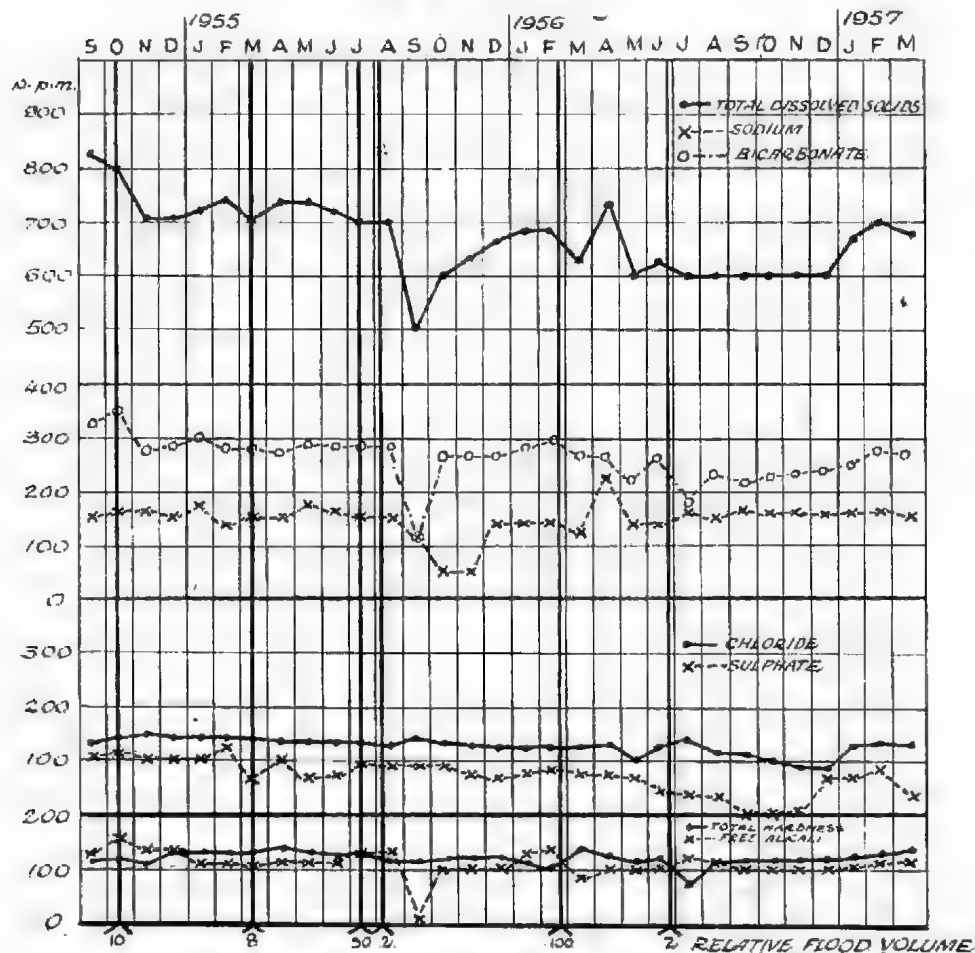


Fig. 4. Composition of monthly samples of water from Army Well No. 2.

**Fluoride:** A modification (Jephcott, 1953) of the method of Huckaby, Welch and Metler (1947) was used.

**Chloride:** Estimated by the universal method of Fr. Mohr.

**Sulphate:** The standard Gravimetric method (Am. Public Health Assoc., 1955) was used.

**Bicarbonate and Carbonate:** Estimated by using selective mixed indicators (Murray, 1954).

**Sodium and Potassium:** Estimated by Flame Photometry, Collins and Polkinhorne (1952).

*Calcium and Magnesium:* Determined by the Schwarzenbach method (1948) as modified by Diehl *et al.* (1950).

*Hardness:* Determined by the Schwarzenbach method (1946), (1947) and (1948), as modified by Betz and Noll (1950).

## RESULTS

The results are as presented in Figs. 2-7 and are tabulated with one co-ordinate being parts per million salts, and the other being time in months. The mid-position of each of the monthly values coincides with the 18th day of that month.

The times of river flow are as shown, and an estimate of the relative strengths of flow is indicated.

## INTERPRETATION

(I). *Lag Period.* Wilson (1957) observed that the lag period between river flow and filtration to the six watering points were as in Table 3.

TABLE 3.

(1) Todd River Well	Immediate.
(2) Town Well	8-10 days.
(3) Army Well No. 1	2 months.
(4) Army Well No. 2	3½ months.
(5) Lot 75 (A.I.M.)	9 days.
(6) Mt. Hillen Motel	5 months.

However, the following factors make these generally unreliable:

- (a) From Fig. 5 (Army Well No. 1) the lag appears more closely to approximate one month than two months, this being especially noticeable in the sodium, bicarbonate, total hardness, and total dissolved solids.
- (b) From Fig. 4 (Army Well No. 2) the lag would again be nearer one than 3½ months. However, the Storm Water drain near No. 2, which has a most irregular flow depending on the distribution of the rain, may account for certain very quick responses—e.g., end of February, 1956, especially in the sodium and free alkali levels.
- (c) Normally the height of the water table will influence flow rate—i.e., a low table will increase the speed of filtration to a large extent. Unfortunately, this is not obvious in the graphs due to the regular distribution of the river flows and the masking effect of the heaviness of the February, 1956, flow after one of the longer dry spells.
- (d) The size of the flood on the river bed influences the filtration rate—i.e., a small flow may not even reach the furthest points and the amount of re-charge will be relatively small—e.g., the medium flow in March, 1955, did not create the magnitude of salinity drop of the two flows in July and August, 1955, the combined flow of which amounts to quite a large factor, especially since the porous structure above the basin would still be quite moist from the first flow. All relevant graphs show this marked response after this dual flow. Naturally, the size of the flood is determined by volume which in itself is dependent on duration of flow, and speed of flow which is in itself dependent on the head of water. The following observations were made for the period September, 1954, to April, 1957 (Table 4).

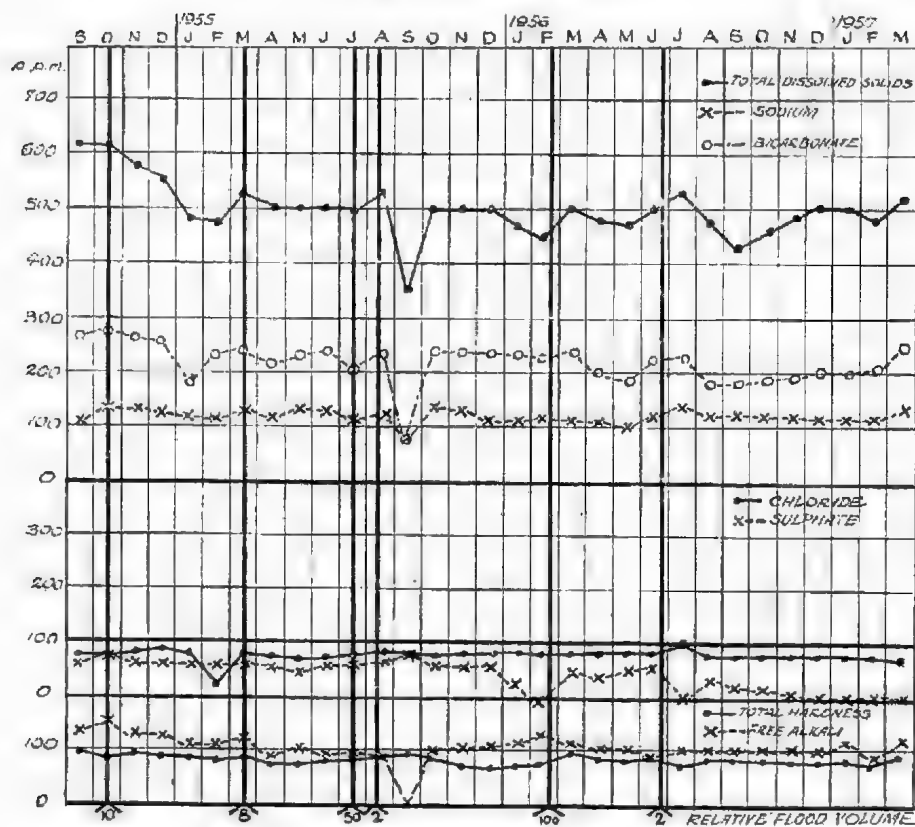


Fig. 5. Composition of monthly samples of water from Army Well No. 1.

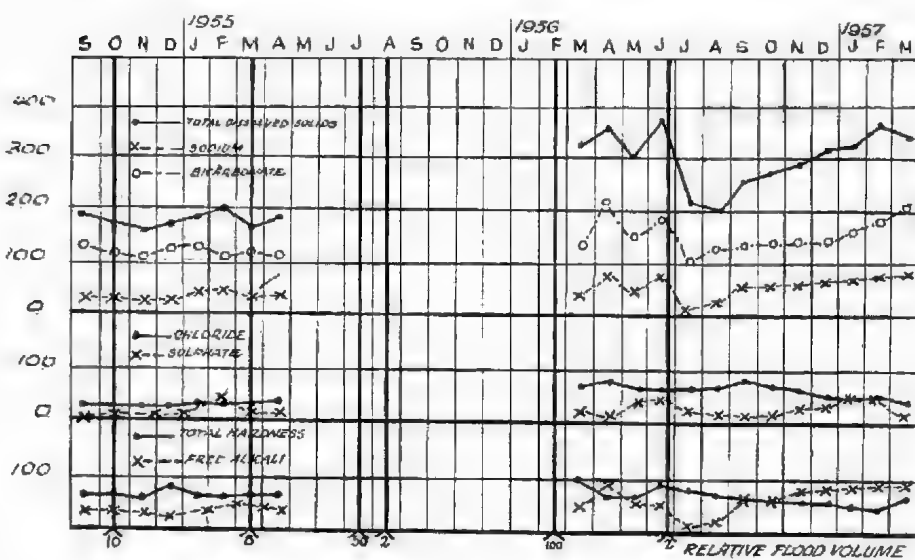


Fig. 6. Composition of monthly samples of water from the Todd River Well.

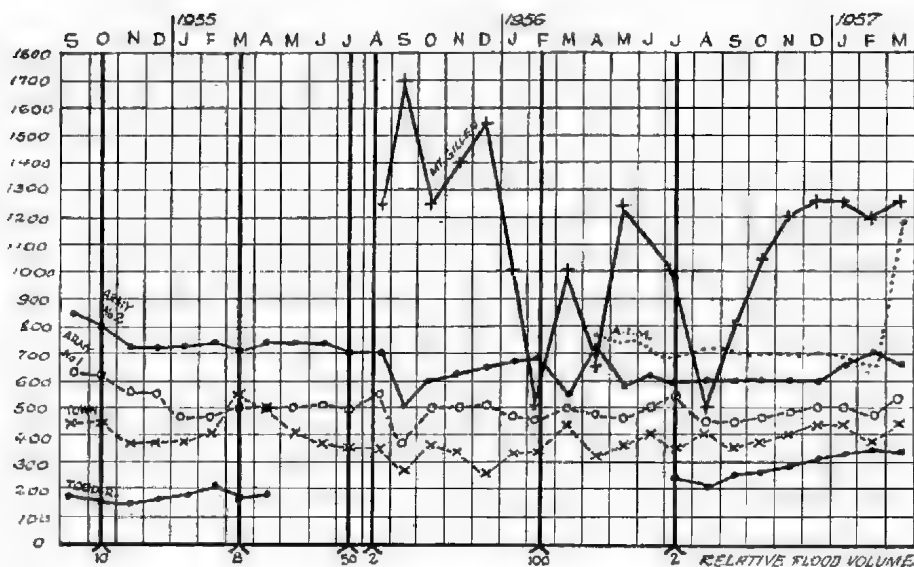


Fig. 7. Comparison of the analyses for Total Dissolved Solids for all wells.

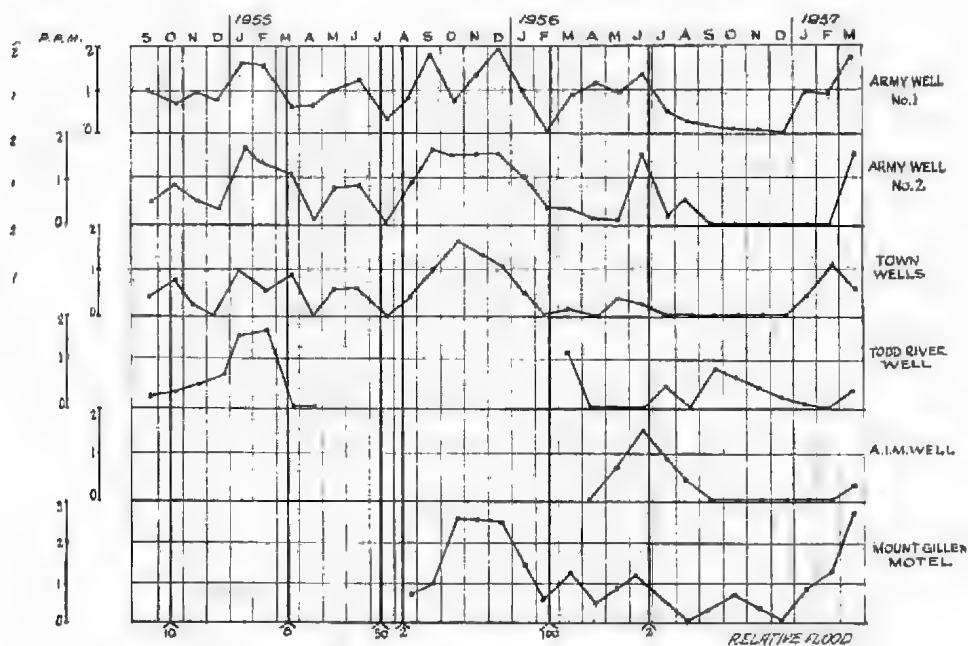


Fig. 8. Comparison of the analyses for Fluorides for all wells.

TABLE 4.

Date	Strength of flow	Strength of flow relative to Feb., 1956
Mid October 1954	Medium	10%
Mid March 1955	Medium	7.5%
Early July 1955	Heavy	50%
Early August 1955	Very small	2.2%
End February 1956	Very heavy	100%
End June 1956	Very small	2.2%

Hence the major effects should be noticed after the flow at the end of July to early August, 1955, and the end of February, 1956, and in practice, this is so, especially as already stated in the dual July-August, 1955, flows.

(II). *Individual Responses.* On first examining the Figs. 2-8 it appears obvious that the responses of chloride, fluoride and sulphate is seldom indicative of river flow, especially with the No. 1 and No. 2 Army Wells and the Town Wells. After the largest flows the fluoride (Fig. 8) in the No. 2 Army Well actually increased and similarly with No. 1. The response of chloride and sulphate follows a most irregular pattern.

This then leaves two other ions, namely, sodium and bicarbonate, two other factors partly dependent on bicarbonates, namely, total dissolved solids and free alkali, and the overall picture of total dissolved solids (Fig. 7).

Naturally, it is best to examine the uncomplicated factors first to see if their response is simple and in this, such is the case. Sodium and bicarbonate respond truly if due allowance is made for time lag and flow strength.

With bicarbonate, in every case, a response is noted, the most obvious being the Army Wells No. 1 and No. 2 and the Town Wells. Allowing the five-month lag for Mt. Gillen Motel, the fall is quite accurate.

Sodium likewise responds to flow in the correct pattern and duplicates the responses of the bicarbonate.

The two ions combined must have, in the majority of cases, a greater effect than all other ions since, apart from isolated cases, the total dissolved solids fall with river flow.

## CONCLUSIONS

In the waters from wells in the Alice Springs basin the most sensitive indicators of the basin recharge are sodium and bicarbonate, these two combined having an effect on the total dissolved solids.

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# **PSEUDO-IGNEOUS ROCKS IN THE TRIASSIC SUCCESSION OF THE SPRINGFIELD BASIN, GORDON-CRADOCK DISTRICT.**

*BY W. JOHNSON AND M. J. BUCKNELL*

## **Summary**

The field occurrence and petrology of some rocks of igneous appearance occurring at the top of the Triassic succession in the Springfield Basin are described. It is concluded that they are natural slags formed by fusion of argillite and coal ash due to heat from a burning coal seam. Some forceful ejection of the molten slag may have occurred. The peculiar mineralogical association in the slags is due in part to the highly siliceous, lime and magnesia-free, composition of the coal ash and the argillite.

# PSEUDO-IGNEOUS ROCKS IN THE TRIASSIC SUCCESSION OF THE SPRINGFIELD BASIN, GORDON-CRADOCK DISTRICT.

by W. JOHNSON AND M. J. BUCKNELL<sup>a</sup>

[Read 9 October 1958]

## SUMMARY

The field occurrence and petrology of some rocks of igneous appearance occurring at the top of the Triassic succession in the Springfield Basin are described. It is concluded that they are natural slags formed by fusion of argillite and coal ash due to heat from a burning coal seam. Some forceful ejection of the molten slag may have occurred. The peculiar mineralogical association in the slags is due in part to the highly siliceous, lime and magnesia-free, composition of the coal ash and the argillite.

## INTRODUCTION

In 1957 a party of students mapping in the Wilson area under the supervision of Dr. A. W. Kleeman collected specimens of indurated or silicified pink and buff argillite, containing leaf impressions of Triassic aspect, from an area 9 miles due east of Gordon.

The possible economic importance of this find was immediately obvious and as soon as the Department was informed one of the authors (Johnson) made a reconnaissance of the area (in November, 1957), when it was found that the silicified pink and buff argillite was the top member of a relatively thick succession of Triassic sediments forming a true structural basin of some considerable areal extent.

On a subsequent brief visit with L. W. Parkin fragments of a material resembling scoria or clinker were picked up on the slopes of a small mesa at the top of which the argillite occurs. At this stage, the analogy between the occurrence and that of the "burnt coal" at Leigh Creek (Parkin, 1953) obviously inviting comparison between the two, a similar origin for the igneous-looking material at Springfield was considered. Then at a later stage, field and laboratory evidence, particularly the similarity between some of the fragments and volcanic ejectamenta, led to our consideration of an igneous parentage for them. Finally, more detailed examination of the occurrence in the field and laboratory has shown that the material originated chiefly from the fusion of the argillite by burning of coal in situ.

Investigation of the field occurrence, described in the first part of this paper was the responsibility of Johnson. Bucknell describes the petrology of the material in the second part.

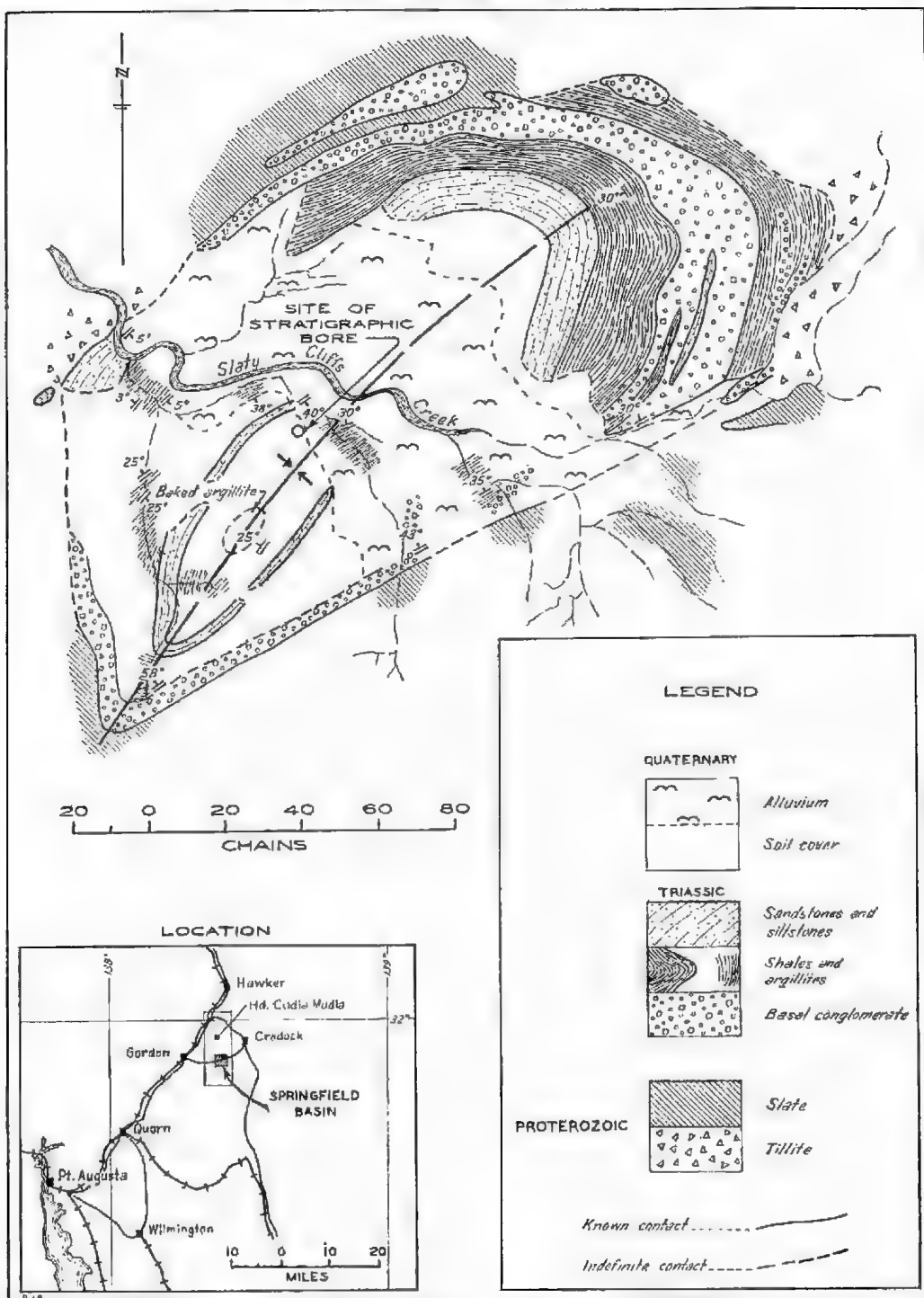
## LOCATION, TOPOGRAPHY AND GEOLOGY

As it is intended to publish a detailed description of the geology of the Springfield Basin at a later date a brief account only is given here to assist in the understanding of the occurrence.

The Basin is situated some 9 miles due west of the abandoned township of Gordon on the Quorn-Hawker road and is reached from a road running directly between Gordon and Cradock.

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<sup>a</sup> Department of Mines, South Australia.



Geological sketch plan of the Springfield Basin near Cradock, South Australia.

It lies in an area of moderate topographic relief and is almost bisected by Slaty Cliffs Creek, a large tributary of Wirreanda Creek. It is elongated in a direction slightly north of east and is asymmetric, the eastern end being broader and having a semi-circular periphery. The length of the Basin is  $2\frac{3}{4}$  miles and its greatest width  $1\frac{1}{2}$  miles.

The Triassic sediments have been extensively eroded and for the most part lie in a topographic depression. A small central mesa, to which the pseudo-volcanic materials are confined, has been left and the basal conglomerate forms a bounding ridge around three-quarters of the periphery of the basin.

Outcrop conditions are poor and nowhere is the full Triassic succession exposed in one section nor is it possible to build up an accurate composite section from a number of stratigraphically overlapping discontinuous sections. Estimates of maximum thickness therefore vary and estimate of total maximum thickness given in this paper is subject to an error which may be in excess of  $\pm 500$  feet. The succession as built up from fragmentary sections is as follows, starting at the top.

Thickness	Description of Lithology
70-90 feet	Pink and buff baked argillite with leaf impressions and fresh water molluscs underlain by whitish paper shales with ash beds at the base.
200 feet	Grey sandy shale, fine-grained sandstone with a coarse-grained lenticular arkose or greywacke at the top.
150 feet	Carbonaceous shales, argillites and siltstones with impure coal seams.
125-140 feet	Chiefly white to yellow siltstone or fine-grained micaceous sandstones with interbedded carbonaceous shales and impure coal seams. Sandstones weathered to concretionary ferruginous box works.
200-700 feet	Carbonaceous shales and argillites with impure coal seams. Gypsum weathers out of shales.
170-940 feet	Red, mauve and buff argillite with beds of red, grey, purple and buff, very coarse-grained sandstone, some containing clay pellets. At western end grades into a predominantly sandstone sequence. At the eastern end argillite is 600 feet thick and overlain by the sandstone sequence 340 feet thick. May contain interbedded coal seams. Sandstones contain leaf impressions.
16-600 feet	Basal conglomerate. Consists of interbedded torrential conglomerate and red and mauve coarse-grained current-bedded sandstone. Conglomerate boulders are predominantly quartzite. Some beds are vein quartz pebble conglomerate.
200 feet	Possible basal beds at eastern end of basin consisting of grey gypsiferous shales.

The best coal seam so far discovered by drilling is 12 feet thick. It is possible that the coal seams responsible for the formation of the pseudo-igneous rocks were much thicker.

#### FIELD OCCURRENCE OF PSEUDO-IGNEOUS ROCKS

All the material of igneous appearance has been found on the top and the side slopes of the small mesa, on the structural axis of the basin. The top 70 to 90 feet of the mesa consists of baked argillite and shale with at least two thin clinker beds at the base and pseudo-basalt dispersed in isolated patches amongst the argillite near the top. Clinker, ropy lava-like masses and "bombs" of pseudo-basalt are scattered erratically over the side slopes and some black,

highly ferruginous lumps are concentrated about a small depression in the surface of the mesa near its central point.

There is a clear-cut division between the normal sediments of the Triassic succession and the "abnormal" rocks on the mesa. The dividing line is the lowest clinker bed. The succession above this bed, so far as can be ascertained from the talus obscured outcrops, consist of (from the top downwards):

60-80 feet	{ Buff and pink argillite with plant remains and fresh water molluscs.
	{ White argillite with molluscs, white paper shale and plants.
14 inches.	Pink, red and greenish-black ash-like material.
6 inches	Clinker.
8-10 feet	White and buff shale.
6 inches	Clinker.

The thickness of the individual beds except for the clinker and ash cannot be determined accurately owing to the talus cover.

The pink and buff argillite is highly siliceous (see analysis in the section on Petrology) and massive. It is hard and tough, though light, and it breaks with a conchoidal fracture and weathers in angular and cuboidal masses. It contains abundant leaf impressions and external casts of molluscs. These are particularly well displayed on weathered faces of the cuboidal and angular blocks. Leaf impressions have been observed within a few inches of completely fused argillite.

The white "paper" shale beneath the pink argillite is a soft, crumbly rock splitting into paper-thin layers with numerous poorly preserved leaf impressions between the layers. In places the bedding of this shale dips vertically and, although apparently in situ, is overlain by normally dipping shale.

The clinker at the base of the abnormal succession consists of irregular small masses of black aphanitic vesicular material whose vesicles are filled in part with white and yellow substances of possible secondary origin. It is embedded in a layer of vari-coloured powdery material bearing a strong resemblance to coal ash, or clay soil strongly heated by burning tree roots.

The only other material of igneous appearance found in situ is the rather coarser grained greenish-black "basalt" occurring in flat slabs and thin seams in the pink argillite. It forms chiefly horizontal tabular masses with irregular out-lines apparently intrusive into the argillite, and in some places completely enveloping pieces of it. In other places thin seams of basalt can be observed in vertical and subvertical cracks leading up into the horizontal layers. Adjacent to the contact, in a zone of varying width, the normal pink or buff colour of the argillite has been altered to a light or dark grey.

The other types of igneous-looking material found are small bomb-like masses; ropy lava, black, highly ferruginous lumps and loose masses of heavy basaltic clinker scattered over the side slopes and the top of the mesa. Examples are figured in the text and their microscopic appearance is described in detail by Bucknell in the petrological section of this paper.

#### THE MODE OF ORIGIN OF THE PSEUDO-IGNEOUS MATERIAL

Although the remarkable resemblance between some of the material and volcanic ejectamenta led to a consideration of an igneous origin for it, the weight of field and laboratory evidence points to it having been formed from argillite or shale by the heat from burning coal or from gases distilled from the coal.

Firstly, let us examine the evidence of the general circumstances of the occurrence. In the coal-bearing basin of Triassic rocks at Leigh Creek, some 150 miles north, similar material has been proved by Parkin (Parkin, 1953) and

Baker (Baker, 1953) to have been formed by heat from burning coal. Likewise, in other parts of the world numerous occurrences of baked clays and natural slags are described by various authors (Sherburne Rogers, 1917). In fact, it seems a normal occurrence in coalfields, given the right type of coal, suitable topography and climate.

On the other hand if the material in the Springfield Basin were truly igneous, it would be unique, for no other volcanic rocks of Triassic age are known in Australia west of the Tasman Geosyncline. This, of course, cannot be taken as proof and stronger evidence against the igneous origin and in support of the burning coal hypothesis is supplied by the form of the material in situ and alteration effects in the argillite. As mentioned above, apart from the clinker lower down the mesa, the "pseudo-basalt" occurs as thin, tabular, horizontal masses and thinner vertical seams or veins, with irregular, but quite sharp, boundaries, showing chilled edges against the argillite. The vertical seams fill small cracks and join the horizontal masses from below.

To explain this form of occurrence as due to igneous activity would require a very fluid lava either flowing by gravity into pre-existing holes and cracks in the argillite or else intruding the argillite from below. Such a fluid lava implies quiet volcanic or igneous activity on a large scale. The fluidity and the intrusive hypothesis are incompatible with the ropy lava and bombs and scoriaceous basalt (clinker) and the postulated large-scale volcanic activity is incompatible with the small volume of igneous material remaining on the mesa.

Two other facts weighing against an igneous origin are the complete absence of volcanic or igneous material lower down in the Triassic succession of the Springfield Basin and the apparent absence of a neck or pipe representing the source of the material.

The unusual chemical and mineralogical composition of the pseudo-igneous material and the variation between its various forms also weigh heavily against their being of common igneous origin.

Finally, there is the problem of the quantity of heat required to bake the argillite. A layer 15 feet thick has been converted to a hard, tough pink or buff rock over an area of 400,000 square feet. Though the amount of heat needed to effect this conversion cannot be calculated precisely, it obviously must have been large and could only have been supplied by a thick sill or lava flow. Either of these would surely have left more traces than the few remnants found scattered over the top and slopes of the mesa. Furthermore, it seems doubtful if even a thick flow or sill could have caused such a thick zone of baking beneath it because of the limited heat transfer in a downwards direction and the lack of heat renewal in the sill, or lava flow, once emplaced.

To pursue the igneous hypothesis to the end it would be feasible to postulate small-scale volcanic activity, operating about a locus centred on the mesa, as a source of the heat. This would have to have been cpi-Triassic to explain the clinker or scoriae beds towards the base of the mesa, overlain by fossiliferous Triassic rocks and surely would have left more evidence of its occurrence.

Turning to the hypothesis of fusion of the argillite by heat from burning coal we find that it presents no inexplicable difficulties. Firstly, coal seams are known to occur at various levels in the Triassic succession of the basin, and they are of a similar type to Leigh Creek coals, which are notoriously liable to spontaneous combustion. Then, as previously mentioned, it requires no unique sequence of events, as the formation of the pseudo-igneous rocks or natural slags, and the large-scale baking of shales overlying coal seams as a result of combustion of the seams, is a well-known phenomenon recorded at various places throughout the world, including Leigh Creek.

The combustion of one or more thick seams beneath the mesa would have quite adequately supplied the heat required to bake the argillite and shales at the top and to partially fuse them.

The patchy occurrence in situ of the pseudo-basalt is explained by the behaviour of the burning coal. Burning and super-heated gases resulting from the partial combustion of the coal, penetrating upwards through cracks formed in the strata overlying the coal, would fuse the argillite in situ in places where the passage of the gases was restricted, or where further combustion took place. Hot gases could pass through cracks of capillary size or not much wider and hence the presence of lava-like material in thin vertical and subvertical seams is adequately explained. The presence of quite extensive slabs of pseudo-basalt is no doubt in part due to flowage of completely fused argillite in the hottest zones or to the extrusion of fused coal ash as postulated by Bucknell.

The presence of bomb-like fragments of pseudo-basalt implies forceful ejection of lava in small masses. It is suggested here that the hot and burning gases from the coal were channelled principally up a crack near the centre of the mesa and eventually travelled upwards at sufficient velocity to simulate the effect of a small volcano. In this phase the small bombs were ejected and perhaps part of the molten fused argillite extruded in the form of ropy lava. The site of this pseudo-volcano is thought to be the small depression near the centre of mesa which is marked by a concentration of heavy, highly ferruginous, black, angular blocks. A concentration of iron near the channel ways for the burning gases is noted by Sherburne Rogers (Sherburne Rogers, 1917).

Further support to the burning coal hypothesis is given by the variation in the mineralogical and chemical composition of the natural slags. This is also discussed in detail by Bucknell.

Other evidence is given by the two clinker beds situated near the base of the mesa. These consist principally of irregular masses of vesicular light and black coloured clinker in a reddish vari-coloured, fine, powdery material identical with the unfused ash from burning coal, and are overlain in places by white paper shales tilted on edge. The latter occur erratically around the mesa and are almost certainly due to slumping of the beds following withdrawal of support by consumption of the coal beneath.

Taking all the evidence into consideration and coupling it with the general circumstances of the occurrence there seems little doubt that the pseudo-igneous rocks and the baking of the argillite and shale were caused by heat emanating from a burning coal seam or seams.

### COMPARISON WITH LEIGH CREEK

The two occurrences obviously invite comparison and have many similarities, such as the baking of the shales, the presence of ash from burning coal and the resemblance of the black aphanitic vesicular clinker at both localities.

There are, however, a number of differences which are probably chiefly due to the differing topography in the two localities at the time when burning took place.

At Leigh Creek, so far as can be ascertained by personal inspection and from descriptions by Baker and Parkin, coarse-grained material similar to the bombs and "basaltic" slabs of Springfield, do not occur. The "basaltic" material at Springfield also occurs in much larger masses and there is definite evidence that it formed by fusion of the argillite.

The mineralogical and chemical composition are obviously different but this may be due principally to difference in composition of the source material. These differences are discussed in more detail in the comments by Bucknell below.



The chief difference, however, appears to be the stratigraphic position of the clinker and other pseudo-igneous material in relation to the burnt coal. At Leigh Creek it is apparently intermingled with the unfused ash formed by burning of the coal seam. At Springfield, the slabs, bomb-like fragments, some of the clinker, and the highly ferruginous lumps are on top of the mesa, are intermixed with the argillite, and on visual evidence, above the level of the burning seam.

The mineralogical evidence suggests that the temperatures attained were higher than at Leigh Creek and it is suggested here, that most of the differences are due to the topographic situation of the coal seams at Springfield.

The mesa occurs on the synclinal axis of the Triassic basin. It is physiographically normal for a mesa or ridge to be left by erosion in such a situation and it is thought ignition of the coal seam or seams took place subsequent to the cycle of erosion which formed the mesa.

This allowed oxygen to have access to the seams around the perimeter of the mesa. Following ignition of the coal, cracking occurred in the overlying rocks, more oxygen was admitted to the coal, and gas, distilled off the coal ahead of the burning zone, began to pass up through the cracks to the surface of the mesa. This would soon ignite at the surface and cause a forced draft up the larger cracks, drawing in more oxygen from the atmosphere and resulting in better combustion and higher temperature. The process would be cumulative, self-sustaining and would eventually result in the formation of blast furnace conditions in one or more of the larger cracks, with argillite being fused up the cracks and at the surface. At the period of maximum combustion and emission of gas it is suggested that blobs of molten fused argillite were ejected to form the bomb-like fragments.

It seems probable that when the ignition occurred the mesa was not much larger than at present, certainly not having more than twice its present surface area. Baking of the argillite to a hard porcellanite type material would assist in the preservation of the mesa by formation of a crust resistant to weathering. It seems probable that it owes its present shape to that cause.

The likely mechanism of ignition would be spontaneous combustion after sudden exposure of the coal seam or seams at one or more points around the perimeter of the mesa by erosion following torrential rainfall. Burning of coal has been noted in America chiefly in areas subjected to rapid cutting of stream channels (Sherburne Rogers, 1917, pp. 2-4).

An alternative explanation would be that the coal seams ignited at a stage when the Triassic sediments were peneplained to a level approximately that of the present surface of the mesa and that the mesa owes its existence to the resistance of the hard-baked argillite. The coal seams could have still burnt out completely due to their synclinal basin structure. However, if this latter explanation were correct, one would expect remnants of baked argillite, clinker and pseudo-igneous material spread over a wider area than its present occurrence. The explanation also introduces difficulty in explaining the ignition of the coal, and on the whole the evidence favours the hypothesis of combustion in comparatively recent times when the mesa was not much different in shape and size than at present.

#### PETROLOGY OF THE PSEUDO-IGNEOUS ROCKS IN THE SPRINGFIELD BASIN

The host-rock for intrusive members of the pseudo-volcanic series is a sili-cified, yet highly fossiliferous argillite. This is often mottled in pink and grey, depending on the state of oxidation of the small amount of ferruginous matter

present. Sometimes the pink areas can be related to small fissures; these would cause oxidation, whether by atmospheric agency or by seepage of hot, oxidizing vapour. Microscopic examination of a thin section from this material reveals a mass of very fine, mainly kaolinitic clay which has been impregnated with secondary silica, giving a hard rock with a conchoidal fracture. There is a tendency for the clay mineral flakes to be orientated in parallel. The ground mass also contains traces of zircon, rutile, a chlorite and opaque matter, while sporadic porphyroclasts of quartz coated with secondary silica occur as well as cavities lined with chalcedony. The chemical analysis of this rock is recorded in Table 1, column B.

Pseudo-volcanic rocks include the following:

Veinlets intruded into the argillite.

Extruded material resembling "ropy lava".

"Volcanic bombs".

Massive vesicular material.

Massive material slightly to non-vesicular.

An example of the argillite with an intruded veinlet is shown in Fig. 1. Xenoliths of the sediment can be seen floating in the intruded material. Fig. 2 is a photomicrograph of a thin section across the contact, showing the radial structure of white and black minerals in the veinlet as well as the concentration of opaque matter along the margin.

A sample of material having the texture of ropy lava is shown in Fig. 3, and a chemical analysis is given in Table 1, column D. The rock contains pseudo-spherulitic grains 0.4-0.8 mm. across, each having a fine-grained centre surrounded by a slightly coarser margin. Rods of alpha-cristobalite, having a roughly radial orientation, are associated with opaque members of the spinel-magnetite family. A polished surface reveals three spinels, with differing reflectivities. X-ray diffraction analysis showed that the unit cell dimensions in order of abundance of the constituents were:  $8.19\text{\AA}$ ,  $8.35\text{\AA}$ ,  $8.40\text{\AA}$ . The first of these is slightly higher than hercynite ( $8.14\text{\AA}$ ), and implies some substitution of ferric iron for aluminium in the octahedral positions of the lattice, since the chemical analysis shows no significant amount of any other element which could enter the spinel structure. The unusual cell dimension suggests a metastable variety arising by rapid cooling from a high temperature. This is confirmed by the presence of cristobalite, which does not normally form below  $1470^{\circ}\text{C}$ .

Photomicrographs illustrating the textures of the thin and polished sections are shown in Figs. 4 and 5.

Some small, rounded cobbles resembling volcanic bombs have been obtained (see Fig. 6). Under the microscope these were seen to possess a similar pseudo-spherulitic texture to that of the "ropy lava". A lower temperature of formation is indicated by the occurrence of alpha-tridymite instead of cristobalite, as well as the formation of cordierite in the more coarse, outer zones of the spherical aggregates. This cordierite has refractive indices (1.56-1.58) corresponding to the iron-bearing member of the series, and is pleochroic from colourless to violet; the optic axial angle is negative and low. It also gives a slightly unusual X-ray diffraction pattern. Locally, this mineral has been pinitized to a pale biotite, associated with chalcedony and silica glass.

In Fig. 7 the texture of the material in thin section is portrayed. Fig. 8 is taken from a polished surface, and shows two members of the spinel family. Most of the grains appear to be composites of the two and would probably all be so if the grain were viewed in three dimensions; this suggests that unmixing has taken place. The spinel and magnetite families probably form mix-crystals at very high temperatures, and these separate into two phases on cooling. Unit

cell dimensions similar to the extreme members in the "ropy lava" were obtained from the X-ray diffraction pattern.

Similar textures are found in the massive vesicular material. But in this case the cordierite has been completely altered to a pale biotite, while silica glass separates the tridymite from the opaque fraction. Many of the cavities are lined with chalcedony, goethite, or limonite; the formation of these substances, as well as the breakdown of the cordierite, was aided by the vesicular texture. Small amounts of zircon and rutile may point to a sedimentary origin for some of the material. A chemical analysis is given in Table 1, column C.

Rocks containing only a few vesicles, or none at all, have been studied. The radial and "spherulitic" structures are absent and the individual crystals larger. Chemical analysis (Table 1, column E) of one containing a few vesicles gives a Si:Fe ratio approximating to fayalite. No fayalite has, however, been observed in the specimen, which consists of an irregular network of tridymite rods with interstitial opaque grains. The latter are mostly titaniferous magnetite, which is martitized to haematite in an irregular fashion. Every grain is criss-crossed with exsolution lamellae, believed to be of another spinel, forming along definite crystallographic directions in the magnetite, and persisting unaffected in the haematite. Some of the grains are partly free of these exsolution bodies, the clear portions being composed of spinel or titaniferous haematite. The features of these opaque grains are shown in Figs. 9 and 10.

Iron-bearing chalcedony fills the interstices of the tridymite rods while some of the former vesicles now contain ferric oxide in various states of hydration. Fig. 11 is a photomicrograph of a thin section taken from this material.

The other variety is non-vesicular and highly magnetic. Roughly polygonal grains of the various spinels already described are set in a siliceous matrix (see Fig. 12). No chemical analysis has been obtained for this rock-type, but it certainly has lower silica and higher iron contents than any of the other species described.

TABLE 1.

	A Coal Ash from lower seam	B Argillites	C Highly vesicular "spherulitic" rock	D "Ropy lava"	E Slightly vesicular rock
SiO <sub>2</sub>	69.14	68.62	52.26	50.04	26.54
Al <sub>2</sub> O <sub>3</sub>	20.03	22.05	17.73	17.88	6.43
Fe <sub>2</sub> O <sub>3</sub>	2.18	2.03	9.3	12.7	45.20
FeO			13.9	12.3	15.0
MgO	0.70	0.10	0.28	0.24	0.10
CaO	1.72	0.52	0.32	0.36	0.16
Na <sub>2</sub> O	1.44	—	—	—	—
K <sub>2</sub> O	0.98	—	—	—	—
H <sub>2</sub> O —	Nil	0.53	0.31	0.43	0.20
H <sub>2</sub> O +	0.24	—	—	—	—
TiO <sub>2</sub>	1.75	1.94	1.62	1.53	0.92
SO <sub>3</sub>	1.43	0.04	0.08	0.10	0.19
Cl	0.01	0.03	0.01	0.03	0.01
MnO	0.04	0.03	0.16	0.25	0.48
Loss on ignition	—	2.21	0.43	0.92	0.14
Total	99.66	98.10	96.40	96.78	97.37

The Chemical Analyses. (Analyst P. C. Hemingway)

The first analysis given in Table 1 refers to the ash from a coal seam lower in the succession. Apart from somewhat higher magnesia, lime and sulphur in the former, the coal ash and the argillite are strikingly similar in composition. Proportion of alkalis in the latter are not given, but the low lime and magnesia content is consistent with deposition in a freshwater and slightly acid environment (Pettijohn, 1956). The low percentage of iron is a significant feature, while the high titania content is not wholly explicable in terms of the mineral composition.

In column E the composition of the massive, slightly vesicular rock illustrated in Figs. 9-11 is given. This is consistent with the minerals present. Highly significant is the fact that Fe:Si ratio closely conforms to that of fayalite.

Analyses of the highly vesicular rock described above, as well as the "ropy lava" (Figs. 3-5) are shown in columns C and D respectively.

It may be safely assumed that the "bombs" illustrated in Figs. 6-8 have a kindred analysis. Columns C and D are alike, and both are intermediate in composition between A and E; in fact, a mixture of 1½-2 parts of the argillite with one of the "fayalitic magna" would give a rock with a similar analysis. The only component that does not conform is the magnesium—the high content of this in C and D may be related to the subsequent development of biotite, although the source of this element is obscure. The rise in  $\text{SO}_3$  content from the argillite to the "fayalitic rock" may have some bearing on the genesis of this series.

#### *Comparison with the Natural Clinker at Leigh Creek*

Baker (1953) has described four samples of clinker collected from the upper coal seam, lobe "D", in the North basin at the Leigh Creek coalfield. This includes light-and-dark coloured vesicular as well as non-vesicular types; he also mentions that the associated shale has been baked and reddened in a similar manner to the argillite from the Springfield basin. Chemical analyses of the coal ash and of the various clinkers are quoted; there has been a significant and not unexpected fall in the proportion of soda, sulphur and chlorine from the former to the latter, as well as a notable rise in lime and alumina. Chemically, the clinkers vary considerably amongst themselves only in their iron and silica contents (inversely) and in the amount of residual soda and sulphur. These facts are summarized in Table 2, columns F and G, in which the analyses are reproduced for purposes of comparison. It is obvious that this material is quite different from any of the specimens from the Springfield basin that have been analyzed. The high proportion of calcium and magnesium in the Leigh Creek clinkers would probably lead to a higher range of fusion temperatures, a more sensitive equilibrium between liquid and solid, and a greater variety of minerals, including pyroxenes (titanaugite, fassaite), plagioclase and gehlenite. Baker quotes fusion temperatures for the ash between 1250° C. and 1300° C. under reducing conditions. Also the molten ash remained within, or close to, the seam, where locally the reducing atmosphere aided the formation of native iron and iron sulphides.

In the Springfield basin the ash appears to have been practically free of the more refractory elements so that a liquid of fayalitic composition was obtained at a temperature of about 1205° C. (Bowen and Schairer, 1938; Barrett, 1945).

The subsequent behaviour of this liquid would depend partly on the oxidation-reduction potential and partly on the small amount of alumina present.

The Leigh Creek clinkers carry spinel, magnetite and haematite as do the fused rocks at Springfield. It seems that the former, by remaining *in situ*, became

locally subject to more oxidizing conditions, as evidenced by the presence of haematite and magnetite. Exsolution bodies of spinel from magnetite (see Figs. 9-10) occurring along definite crystallographic directions are reported from both. The Leigh Creek spinel would appear to be more magnesian, as would be expected from the composition of the mineral matter in the coal seam.

#### *Comparison with Overseas Occurrences*

Sherburne Rogers (1917) has discussed the factors conducive to spontaneous combustion of a coal seam, and describes the effect of this on strata overlying seams in various parts of Montana, U.S.A. The strata are silicified plant-bearing shales; near the seam they are red or mottled by baking, as at Springfield. Fusion has resulted in vitrified, glassy and recrystallised slags, the first sometimes having a ropy lava texture and the second containing true spherulites. Both these varieties are devoid of recognisable crystals. The recrystallised material from the sandy shale has diopside and labradorite. Magnetite and almandite also occur; the latter should change to hercynite, iron cordierite and fayalite above 780° C. at normal pressures (Yoder, 1955) and this would be an unusually low temperature of crystallisation. When derived from aluminous shale, the slag has sillimanite, cordierite and ? spinel. In the chimney above the coal seam is a mass of spinel and haematite, and it is suggested that iron is distilled from the seam as ferric chloride vapour.

At Springfield, however, the ash from a lower seam is practically devoid of chlorine, and this element is not significantly enriched in the pseudo-volcanics as compared to the argillite; contrast the rise in the sulphur content. The chemical analyses of the two types of Montana clinker is shown in Table 2, columns H and I, and the composition is intermediate between that of the Springfield and Leigh Creek coal ashes for most of the constituents.

Fused shale from East Wyoming (Bastin, 1905) has oligoclase, pyroxene, cordierite, magnetite and haematite, while magnetite, cordierite, epidote, plagioclase, tridymite and spinel are reported in similar rocks from the Boehmischen Mittelgebirge (Hibsch, 1908).

TABLE 2.

	F	G		H	I
SiO <sub>2</sub>	21.3	25.5	±0.0	65.41	58.30
Al <sub>2</sub> O <sub>3</sub>	14.85	21.6	±3.0	11.94	20.50
Fe <sub>2</sub> O <sub>3</sub>	12.3	12.3	±8.5	7.38	4.23
FeO	—	3.4	±2.6	0.76	0.46
MgO	5.2	4.3	±0.6	1.50	1.31
CaO	14.75	23.4	±1.8	5.02	4.40
Na <sub>2</sub> O	10.12	2.0	±2.0	2.83	1.46
K <sub>2</sub> O	0.6	0.3	±0.3	1.96	2.28
H <sub>2</sub> O—	—	0.4	±0.3	0.08	1.03
H <sub>2</sub> O+	—	1.2	±0.6	0.50	1.90
TiO <sub>2</sub>	1.20	1.4	±0.05	1.17	0.28
SO <sub>2</sub>	14.81	S=2.11	±2.1	0.22	0.10
Cl	3.56	0.2	±0.2	—	—
CO <sub>2</sub>	—	0.8	±0.2	1.57	3.37
P <sub>2</sub> O <sub>5</sub>	1.76	2.0	±0.8	trace	trace
MnO	—	0.1	±0.2	—	0.18

F Leigh Creek Upper Seam "D" Lobe Ash (Analyst T. W. Dalwood)

G Leigh Creek Clinker—Average and variance of four analyses (Analyst G. C. Carlos)

H Montana U.S.A. Recrystallised from Sandy Shale (Analyst G. C. Carlos)

I Montana U.S.A. Recrystallised from Aluminous Shale (Analyst G. S. Rogers)

### *Petrogenesis*

The spontaneous combustion of low-grade coal, whether at surface or in disused mines, is a well-known phenomenon occurring in various parts of the world. Ignition of surface exposures may arise where the surface gradient is steep, such as would arise from a quick cutting stream (Sherburne Rogers, 1917) or where the seam is capped by a fairly hard indurated rock as at Springfield. Once the coal has ignited, it will burn away from the exposed face. As the Springfield outlier has an elliptical shape the coal would have burned towards the centre, the overlying strata slumping down in the wake of the advancing fire. Both low and high angle fissures were probably developed, the former acting as inlets for the air and the latter as chimneys for the combustion products and distilled volatile constituents. Heat accumulated owing to the confined space and poor thermal conductivity of the coal, and temperatures of 1200° C. or more were attained.

Reducing conditions prevailed at the level of the coal seam, so that at about 1205° C. a liquid of essentially fayalitic composition was produced. The source of the iron necessary for this liquid is obscure, since both the ash from a lower seam and also the argillite are very deficient in this element; possibly it came from ferruginous bands within the seam or immediately above it. Coal seams always fire at or near the top (Sherburne Rogers, 1917). However, a liquid of fayalitic composition would melt out, whatever the local Si:Fe ratio, and would dissolve the residual constituent only when the temperature was further elevated. Generally, however, it would be squeezed up into the chimney cracks by the pressure of the overlying strata, as a foaming liquid containing bubbles of distillate (methane and other hydrocarbons, hydrogen), carbon monoxide, and possibly some hydrogen sulphide. In the upper fissures the addition of air led to further oxidation of the volatiles. Heat from this reaction raised the temperature still further and enabled the liquid to dissolve up to twice its own weight of country rock. When distillation ceased this was not possible, so that the non-vesicular specimens are poor in dissolved silica.

At the surface a temperature of more than 1470° C. was sometimes attained, so that on chilling cristobalite was formed. Sudden slumping of the overburden caused the liquid to spurt up and be extruded in the form of rounded nodules or "ropy lava". The former may have been ejected from smaller fissures, where the high ratio of surface area to volume resulted in a higher heat loss and a lower maximum temperature, so that tridymite instead of cristobalite was formed.

The change from reducing to oxidizing conditions affected the subsequent crystallization. Goldschmidt (1954) suggests that an oxidizing potential would prevent the formation of fayalite, spinel and magnetite being produced instead.

It has been calculated that the complete combustion of a foot of sub-bituminous coal would provide enough heat to raise the temperature of 100 feet of shale by 300° C. Considerable heat loss would arise at the level of the seam especially in the initial stages as well as where the fused material was extruded. However, heat loss at the ends of narrow fissures would be small compared to that conducted out through the country rock. It therefore appears that enough heat would be evolved to bake and redden the argillite. This process would carry on for some time after the material in the fissures had solidified.

### CONCLUSION

The field evidence points to the basalt-like clinkers and other material of igneous appearance being natural slags formed during combustion of a coal seam under a small mesa in the triassic sediments of the Springfield Basin. The



petrological evidence supports this and indicates that the slags were formed by fusion of coal ash and argillite and modified by interaction between slag and unfused argillite.

Combustion of the coal seam was complete due to its topographic situation, outcropping around the perimeter and some height above the base of the mesa. This probably also contributed to a rapid rate of burning and consequent relative rapid rise in temperature of the rocks above the coal seam.

Partial differentiation of the semi-fused coal ash by pressure from the superincumbent strata accounts for some of the peculiarities of composition of the natural slags.

### ACKNOWLEDGMENTS

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FIG. 1.—Argillite, with intruded vein of molten rock. One-half natural size.



FIG. 4.—Thin section of "ropy lava", showing texture, x145.

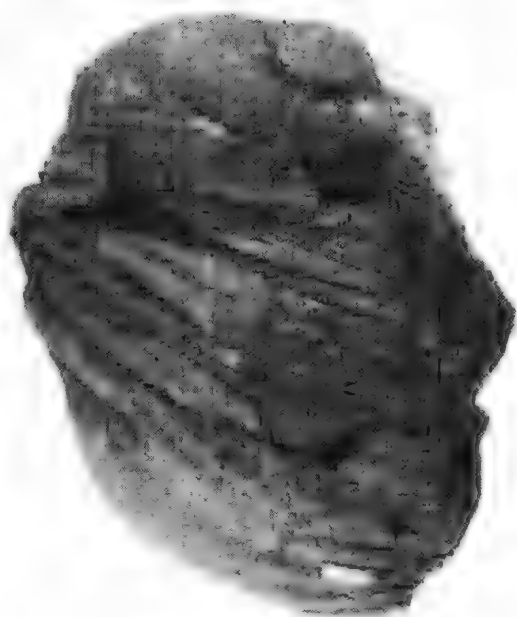


FIG. 3.—"Ropy lava",  $\frac{5}{16}$  x natural size.



Fig. 5.—Polished surface,  $\times 360$ , showing three kinds of spinel.

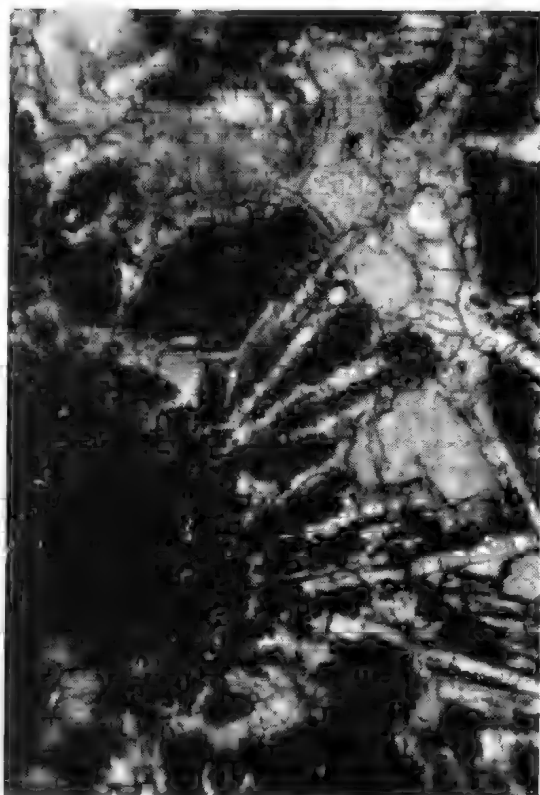


Fig. 7.—Thin section of cobble,  $\times 45$ , with tridymite rods, and larger crystals of cordierite.

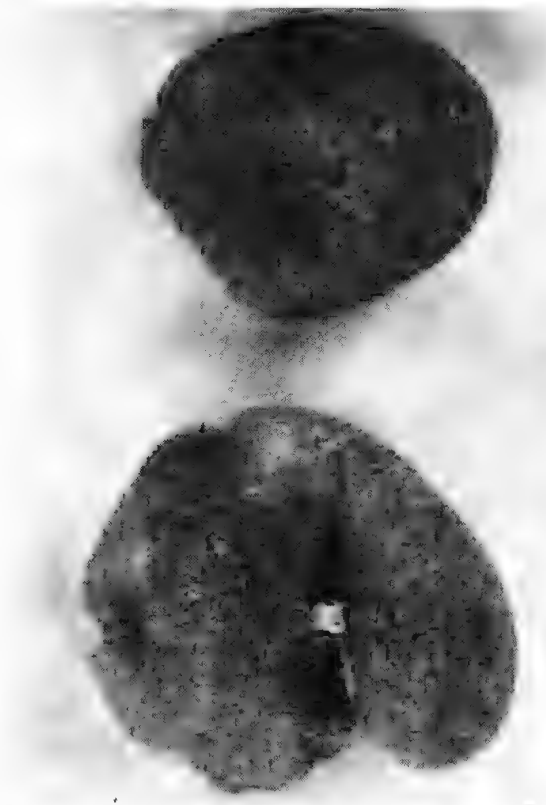


Fig. 6.—Extruded "cobble". Natural size.



Fig. 8.—Polished surface,  $\times 360$ . Two spinels, possibly from mix-crystals.



Fig. 10.—Polished surface,  $\times 360$ . The clear crystal is titaniferous haematite.



Fig. 9.—Thin section,  $\times 145$ . Tridymite, with some iron-stained chalcodony (grey) and magnetite (black). On the left-hand side a former cavity is filled with goethite.

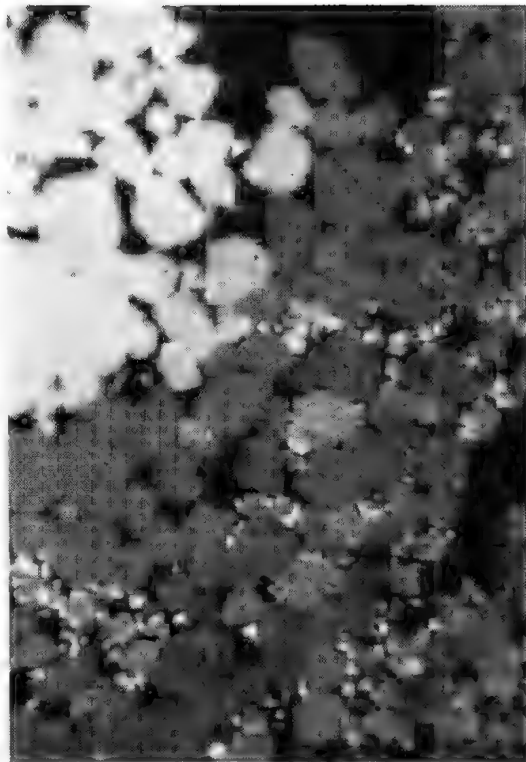


Fig. 12.—Polished surface,  $\times 360$ . Partly euhedral grains of spinel and magnetite.



Fig. 11.—Polished surface,  $\times 360$ . Exsolution lamellae of ? spinel, in partly martitized titaniferous magnetite. The large clear crystal is also of spinel.

# A SURVEY OF THE MOSQUITOES OF COONALPYN DOWNS, SOUTH AUSTRALIA.

by E. J. WATERHOUSE\*

[Read 9 October 1958]

## SUMMARY

A survey of the mosquitoes of Coonalpyn Downs during the period January to March, 1952, is reported. Twelve species have been collected either as larvae or as adults; three are recorded from South Australia for the first time.

The relationship of the distribution and abundance of various species of adults to the type and frequency of breeding places has been investigated.

## INTRODUCTION

The Australian Mutual Provident Society in 1949 initiated a land development scheme in the Upper South-East of South Australia. During January to early March, 1952, at the request of this Society, the author made a survey of the mosquito fauna on a portion of the Coonalpyn Downs in the area to be developed. The primary objectives were to determine the mosquito species occurring in the area, whether these could be vectors of myxomatosis in rabbits, and how the disease could be exploited. The area surveyed was approximately 200 square miles.

The present paper records some notes on the biology and distribution of the mosquitoes collected during this survey. Mosquitoes had not previously been collected from the area although Lines collected to the north-west and west during 1951-1956 (in preparation), Waterhouse in 1953-1954 made collections further north in the Murray Mallee in South Australia (in preparation), and Douglas collected in the north-west Mallee area in Victoria in 1955-1956 (in preparation).

Development of this land has been hindered by the low fertility of the soils and by problems of management. Settlement is now rapidly expanding, largely as a result of an increased knowledge of the fertilizer requirements of the soils and improved methods of clearing. Much of the area in this survey had not been cleared or settled. It was anticipated that an increase in the rabbit population following clearing might menace sown pastures.

## DESCRIPTION OF THE AREA

The topography, soils, vegetation and availability of water in the Coonalpyn Downs area surveyed have been described in detail by Taylor (1933), Coal-drake (1951), Blackburn *et al.* (1953), and by Jackson and Litchfield (1954).

The area is part of an extensive sandy plain between the South Australian coast and the Victorian border and is covered mainly by low shrubs, known collectively as heath, and by mallee-eucalypt rarely higher than 15 feet.

The area is in the "warm temperate" zone of Davidson (1936) with a mean annual temperature of 55-60° F. and a growing season for pastures, as defined by

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Trumble (1948), from May to November. The rainfall has been analysed by Coaldrake (1951), who indicates that the greatest local variations in the monthly totals occur in the summer months. Because of the porous nature of the soils, surface streams have not developed in the area, and surface waters are restricted to shallow swamps, excavated water-holes and dams, and shallow wells.

Two approximately parallel ranges of sand-covered, limestone hills, the Stirling Range and the Black Range, 100-200 feet in altitude and running north-west to south-east, divide the area surveyed (see Fig. 1).

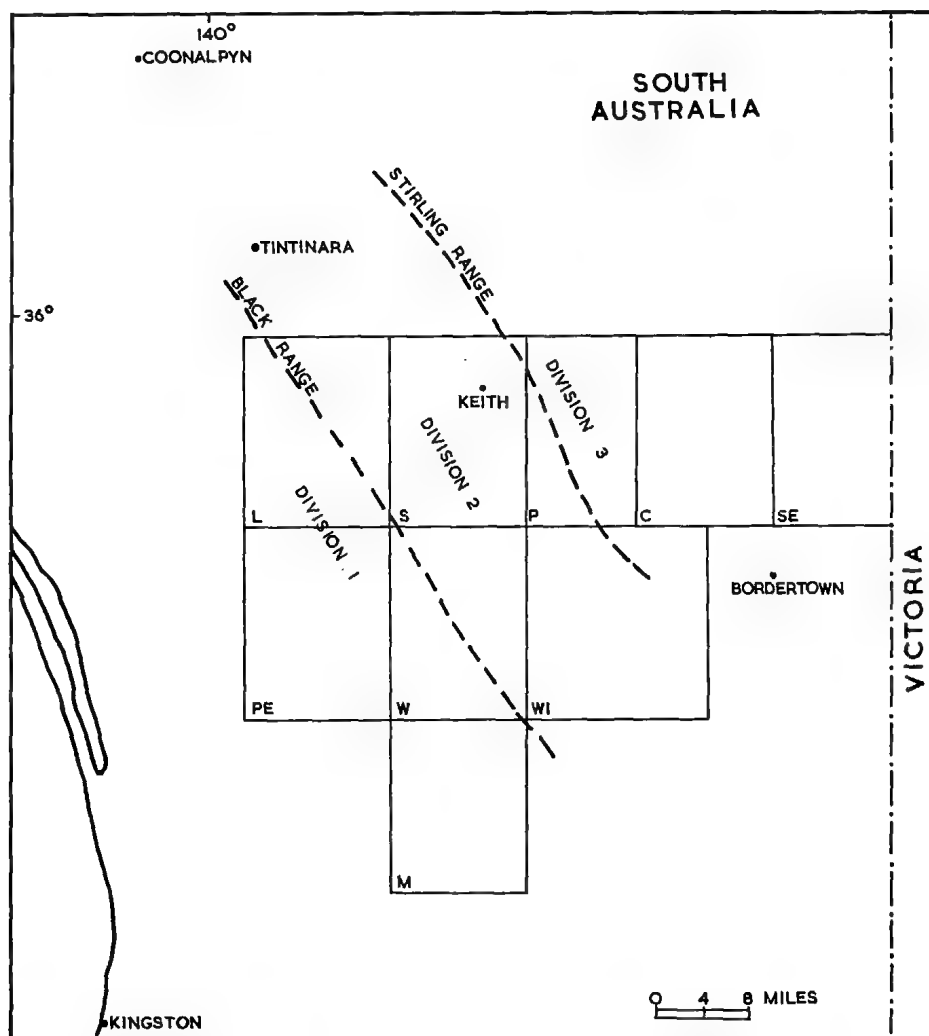


Fig. 1.—Locality Map: Location of portion of Coonalpyn Downs in South Australia surveyed for mosquitoes—1952. Key to Hundreds: C—Cannawigara. L—Laffer. M—Marcollat. P—Pendleton. PE—Petherick. S—Stirling. SE—Senior. W—Willalooka. WI—Wirrega.

The area south-west of the Black Range (referred to subsequently as Division 1) was relatively undeveloped at the time of the survey and is comprised largely of swampy flats. These flats are mostly very saline and carry either samphire (*Salicornia* spp., *Arthrocnemum* spp.) in the wetter areas, or cutting-

grass (*Cladium* spp.) or red-gum (*Eucalyptus camaldulensis*) in those areas which are wet for only part of the year and are less saline than the samphire flats. In Division 1, during the period of the survey, most of the mosquito breeding-places were waterholes. Most swamps were dry; those which did contain water were relatively unproductive of mosquitoes.

Between Black Range and the Stirling Range (referred to subsequently as Division 2) the area had been largely developed for agricultural purposes. The natural vegetation consists of heath (*Banksia* spp., *Casuarina* spp., and *Xanthorrhoea* spp.), mallee-heath associations (*Eucalyptus incrassata*) on well-drained soils, mallee-broom association (*E. incrassata*, *Melaleuca uncinata*) on the moderately drained soils, and mallee-tea-tree associations (*Eucalyptus* spp. and *Melaleuca* spp.) on the poorly drained soils which are liable to water-logging and are very saline.

In Division 2 the potential mosquito breeding-places are of two types: (1) Shallow ground waters, which may be at the surface or down to 25 feet below the surface. These are saline, but provide the bulk of the mosquito breeding-places in the form of shallow wells and water-holes; (2) Much less saline waters pumped from 100 to 200 feet; these supply the stock-watering tanks and troughs, which are common. The latter potential mosquito breeding-places were of much less importance than those provided by the shallow ground waters.

East of the Stirling Range (referred to subsequently as Division 3) the area covered by the survey was mainly undeveloped. The vegetation is a complex of mallee-broom-bush association (*Eucalyptus incrassata*, *E. leptophylla*, *Melaleuca uncinata*) and pink-gum (*E. fasciculosa*).

In this division the only source of permanent underground water is in the marine limestone 50 to 200 feet below the surface. The salinity of the water is high. Surface waters in the form of soakages, springs and dams are not common. Gilgai zones occupying the lowest or most poorly drained sites are extensive in the Hundred of Senior and extend westward into the Hundred of Cannawigara; small areas also occur in the Hundred of Pendleton. These gilgai areas probably provide breeding places for mosquitoes during wet seasons.

## METHODS

Ten visits were made to Division 1 from 12.1.52 to 29.2.52. Eighteen waterholes, representing approximately a third of the estimated number within the Division, were examined for mosquito larvae. Most of these were inspected only once, three were visited twice, and two were visited on three dates, at approximately weekly intervals in February. Two shallow wells, one inspected twice, and one fresh-water rain tank, one small dam, and two swamps were also examined. Of the latter group, the swamps provide the major potential breeding areas for mosquitoes. Because this Division is relatively undeveloped, wells, tanks and dams were rare.

During the same period, six visits were made to Division 2 where three waterholes, nine wells, five tanks, and eight troughs were examined for mosquito larvae; these all received one visit each. Water-holes were not as frequent as in Division 1; the important breeding places were provided by shallow wells. Only a small proportion of the total potential breeding areas was visited.

Four visits were made to Division 3 from 17.1.52 to 11.3.52. Nine waterholes or soakages (practically the total number in the Division), two of which were dry, seven wells, and two dams were examined. The wells comprised approximately half those present in the area; only two could be examined for mosquito larvae as the depth to the water surface in the others was over 100 feet.



Mosquito larvae were sampled by dipping from surface pools and shallow wells, and from deeper wells by lowering a conical net which had a glass tube fitted at the bottom of the net. Individual larvae were reared where possible, the resulting adults pinned, and the corresponding larval and pupal sloughs and representative samples of larvae preserved in Pampel's fluid. Adult mosquitoes were collected in the field in a cyanide killing bottle as they came to man.

## RESULTS

### Larval Mosquitoes

Five species of mosquito were collected as larvae. These were:

- Anopheles (Myzomyia) annulipes* Walker
- Aedes (Finlaya) notoscriptus* (Skuse)
- Aedes (Ochlerotatus) camptorhynchus* (Thomson)
- Culex (Culex) globocoxitus* Dobrotworsky
- Culex (Culex) pipiens australicus* Dobrotworsky and Drummond.

Of these five, *An. annulipes* and *C. globocoxitus* were commonly found together and were the most widespread. The latter were frequently more abundant (5 to 10 per dip) than *An. annulipes* (1 to 5 per dip). Although adults of *Aedes alboannulatus* were more abundant than other species of mosquitoes, the larvae were not found.

### Larval Habitats

The main mosquito breeding-places during this survey were water-holes and shallow wells; 24 out of 28 water-holes, and 10 out of 15 shallow wells contained larvae. Two out of six tanks contained larvae; one of these was the only fresh-water rain tank with the top practically covered and it contained large numbers of *A. notoscriptus* larvae. The other was an open tank with a few *C. globocoxitus* larvae which were probably pumped into the tank with the water from a well. Four out of eight troughs examined contained larvae of *C. globocoxitus*, *An. annulipes* and *C. pipiens australicus* in that order of dominance and frequency; these four troughs were very dirty and were those with the ball-float covered so that a relatively sheltered situation was provided. The only species found in the shaded edges of the swamps examined, or in the small pools nearby, was *An. annulipes* in low numbers. No mosquito larvae were found in the eight dams examined; which all had relatively large expanses of exposed windswept water-surfaces with no emergent vegetation.

The water in most of the breeding places ranged from non-saline to slightly saline as determined by tasting.

Details of the main larval habitats are as follows:

#### (a) Water-holes

The water-holes were of two main types—natural surface pools, and holes excavated to expose the water table. The latter had three steep sides varying in height from 3 to 6 feet, and the water, which was up to 3 feet below the ground level, was directly available to stock on the fourth side. Thus the water surface along three sides was relatively well sheltered. The surface areas of these pools were rarely greater than 200 square feet.

The larvae of *C. globocoxitus* and *An. annulipes* were frequently found together. Neither species appeared to tolerate very saline conditions, but *C. globocoxitus* seemed to be more tolerant of moderately saline conditions than *An. annulipes*. *A. camptorhynchus* larvae were found only in very saline pools.

#### (b) Wells

Larvae were more common in wells in which the depth to the water surface was less than 12 feet. Larvae of *C. globocoxitus* were collected from wells in



which the water surface was as much as 24 feet below ground level; larvae, probably of the same species, but not specifically identified, were collected in the Hundred of Pendleton (Division 3) from a well in which the water surface was 80 feet below ground. *C. globocoxitus* occurred in both covered and uncovered wells. In contrast, *An. annulipes* was found only in wells in which the surface of the water was not more than 12 feet below ground level and was exposed to sunlight. These two species were occasionally found together, and one or the other species was nearly always found to be present in the wells. Few *C. pipiens australicus* larvae were found, either associated with these two species or alone.

Few of the larvae which were collected from wells were reared to adults as they had a much higher mortality rate in rearing tubes than those which were collected from the sunlit water-holes.

#### Adult Mosquitoes

Eleven species of adult mosquitoes were collected. These were:

- Anopheles (Myzomyia) annulipes* Walker
- Anopheles (Anopheles) atratipes* Skuse
- Aedes (Finlaya) alboannulatus* (Macquart)
- Aedes (Finlaya) notoscriptus* (Skuse)
- Aedes (Ochlerotatus) camptorhynchus* (Thomson)
- Aedes (Ochlerotatus) sagax* (Skuse)
- Aedes (Pseudoskusea) bancroftianus* Edwards
- Aedes (Chaetocruimyia)* undescribed sp.
- Aedes (Macleaya) tremula* (Theobald)
- Culex (Culex) globocoxitus* Dobrotworsky
- Culex (Culex) fatigans* Wiedemann.

Of these, *An. atratipes*, *A. bancroftianus*, and an undescribed species of *Aedes (Chaetocruimyia)* were recorded for the first time from South Australia. Locality and date records for these species are as follows:

#### *Anopheles atratipes*

Hundred of Marcollat, Section 7, "Leder Swamp", 26.2.52.

#### *Aedes bancroftianus*

Hundred of Pendleton, Block H, 28.2.52.

#### *Aedes (Chaetocruimyia)* sp. (undescribed)

Hundred of Senior, Section 42, 17.1.52; Section 36, 11.3.52;

Hundred of Pendleton, Section 3, 28.2.52;

Hundred of Petherick, Section 2, 23.2.52.

Adult mosquitoes generally, as determined by their biting of man, were present in relatively low numbers. For those species present in sufficiently large numbers to enable comparisons to be made, it appeared that in Divisions 1 and 2 *A. alboannulatus* was more abundant than *An. annulipes*. In Division 3 these two species were equally common but were much less abundant than in Divisions 1 and 2.

The only other adult mosquito which was at all widespread or abundant was *A. (Chaetocruimyia)* sp. which was largely confined to Division 3.

### DISCUSSION

At the time of the survey, *C. globocoxitus*, *An. annulipes*, and *A. alboannulatus*, either as larvae or adults, were widespread; these species occurred most frequently in Division 1 and least in Division 3. This is closely related to the relative availability of suitable breeding places in the three Divisions. Like-

wise, *A. camptorhynchus* larvae and adults were found only in Division 1, the only one in which very saline pools occur. *C. pipiens australicus* was found only in the non-saline and very slightly saline waters in Divisions 2 and 3. The widespread distribution of *A. (Chaetocruomyia)* sp. in Division 3 suggests that its range probably extends further east and north into similar country in the "Big Desert" area in South Australia and Victoria.

#### ACKNOWLEDGMENTS

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# AN ACCOUNT OF *PLAGIORCHIS MACULOSUS* (RUD.), ITS SYNONYMY AND ITS LIFE HISTORY IN SOUTH AUSTRALIA

BY MADELINE ANGEL

## Summary

A historical account of the parasitic trematode *Plagiorchis maculosus* (Rud.) since its description in 1802 is given. An amended diagnosis of the species is given. It is recorded from South Australia from the birds *Hirundo neoxena*, *Rhipidura leucophrys*, *R. flabellifera*, *Gymnorhina hypoleuca*, and *Pomatostomus superciliosus*. Two trematodes from *Grallina cyanoleuca* may also be *Plagiorchis maculosus*. To avoid confusion in taxonomy, it is urged that authors give full details of treatment and fixation of worms. It is also desirable to know the age of the worm, and the number of specimens examined. Given details such as these, it is possible to make allowance for characters which may be variable. Tables are given, showing measurements of *P. maculosus* recorded by different authors since Rudolphi; of other species which are discussed for synonymy; and of South Australian specimens which have been studied in the present investigation. A history of knowledge of the life history is followed by an account of the life history in South Australia, in *P. maculosus* from swallows, wagtails, babblers and, experimentally, chickens. A description of the various larval stages is given. The size of the stylet in the cercaria should not be used as a diagnostic character in this species. The synonymy is discussed. *Plagiorchis clelandi*, *P. spatulatus*, *P. notubilis* and *P. orientalis* are given as synonyms. It is suggested that examination of the types of *Plagiorchis* sp. from insectivorous birds, or animals which (normally or accidentally) ingest insects, may reduce the number of species still further. *Plagiorchis russii* is shown to be invalid, being a synonym of *P. potanini*. The three varieties, *Plagiorchis maculosus anatis*, *P. maculosus citelli* and *P. maculosus motacillae*, are discussed. The variety *citelli* shows no differences from the typical form, and is made a synonym. If the large size of the testes is a uniform character, the variety *anatis* stands, with var. *motacillae* a synonym.

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*Plagiorchis russii* is shown to be invalid, being a synonym of *P. potanini*.

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## INTRODUCTION

In 1802, Rudolphi described *Fasciola maculosa* from the terminal part of the intestine of *Hirundo rustica*. He gave as synonyms *Fasciola hirundinis* Froelich (1791) and *Distoma hirundinum* Zeder (1800), from the rectum of *Hirundo apus* and *H. urbica* respectively, mentioning that, though their descriptions differed in many respects, the worm itself was very variable. In 1809 (p. 374) he referred to it as *Distoma maculosum*, and in 1819 (pp. 382-3) recorded it (by this name) from *Caprimulgus europaeus*.

The species was recorded or listed by various authors in the following century, but it was not until 1902 that an adequate figure was published, by Braun, who assigned the species to the genus *Plagiorchis* Lühe (1899).†

\* Department of Zoology, University of Adelaide. -

† On the same day that Lühe's generic name appeared, Looss published the name *Lepoderma* for the same genus. Lühe did not name the genotype till later, and it would seem that *Lepoderma* should have had priority. However, relatively few workers have used the name since that time, and *Plagiorchis* seems now commonly accepted, although Dollfus in 1949, referring to family Lepodermatidae, gave Plagiorchidae as a synonym.

Braun examined Rudolphi's specimens, which he stated had deteriorated over the years, so that the species could not be sufficiently described from these specimens alone. However, they corresponded with similarly named examples from the Vienna, Munich and Königsberg collections. He gave figures of the dorsal and ventral view of a specimen from *Hirundo rustica* from Königsberg. From the magnification given the worm would be  $2.7 \times 0.8$  mm. Braun gave no real description of the species, but he referred to the variability in the size of the suckers (even among animals of the same size) and in the arrangement of the yolk glands.

In 1909, Lühe gave a key and a description of 6 species of *Plagiorchis*. As this was the first real description of *P. maculosus* to be published, a translation is given here:—

About 2.0-2.5 mm. long; 0.5-0.7 mm. wide; oval in cross-section. Oral sucker about 0.2-0.3 mm. Ventral sucker approximately at end of first third of body length; about 0.15-0.20 mm. in diameter. Pharynx smaller, and ovary usually somewhat smaller, than the ventral sucker. Yolk glands lateral, extending from the pharynx to the hind end of the body; only at the hind end spreading out to meet on the dorsal surface. Testes comparatively large, spherical, occupying about the third quarter of the body length. Uterus behind testes forming no clearly defined loops.

Braun's figure and Lühe's diagnosis seem to have formed the basis of subsequent identifications. Table II lists the measurements recorded for *P. maculosus* from many hosts since Lühe's time.

In 1929 Massino gave a key to 24 species of the genus. This was based primarily on the position of the testes and secondarily on the relative sizes of ovary and testes.

In 1931, Schulz and Skorow proposed two subgenera for *Plagiorchis*, namely, *Plagiorchis* and *Multiglandularis*, according to whether the yolk glands do not meet in front of the ventral sucker, or join to form a marked commissure. *Plagiorchis maculosus* was placed in the subgenus *Plagiorchis*.

In 1937 Olsen published a study of the *Plagiorchinae*, which included a key to the subgenera and species of *Plagiorchis*. There were 43 species and 2 subspecies. (Olsen also listed 4 species the descriptions of which were not available to him.) It would seem that many of the characters given in Olsen's key are subject to a good deal of variation within any one species, and the key is, therefore, not very satisfactory. In 1932 Schulz had expressed the opinion that a critical revision of the whole genus was necessary; *Plagiorchis* contained some 50 species from various orders of vertebrates, but specimens showed great variability, and a much-needed revision might reduce the number of species to 15 or 20. Other authors have shared Schulz's opinion of the desirability of a revision of the genus, but so far this has not been made.

There are now some 90 described species of *Plagiorchis*, and the number seems likely to grow unless authors will appreciate the necessity of allowing for some considerable amount of variation of characters within a species, whether due to differences in age, fixation or treatment, etc., and for the possibility that some species may occur in a more or less wide range of hosts.

Ulmer (1952), in a critique of methods for the measurement of parasitic worms, thought that much of the present-day confusion in taxonomic studies might be avoided if authors would state, as far as possible, the age of the worms, whether specimens had previously been flattened, and what fixatives were employed. Cover glass pressure may cause marked changes, not only in body size, but also in the shape and relationship of non-muscular organs, such as the genitalia, which are often of taxonomic importance.

Gifford (1955) examined 300 specimens of *Allasogonoporus marginalis*, and reported that the relative positions of internal structures of the worm change

during growth. Flattening during preparation for staining also will alter size, shape and position of these structures.

Callit (1946) gave measurements for a living specimen of *Lepoderma maculosum* (Rud.), and for the same specimen, fixed. These figures are shown in Table 2. It will be noticed that though the size of the oral sucker remained unchanged, the ventral sucker was smaller in fixed than in living material. The pharynx, too,  $140 \times 75 \mu$  living, was only  $75 \times 50 \mu$  fixed.

One of the characters Olsen used in his key was the position of the oral sucker, which, according to the key, is sub-terminal in *Plagiorchis maculosus*. In his description, Rudolphi stated that the mouth aperture was terminal. Among 14 specimens collected from 7 swallows from Wellington, S. Aust., in March 1956, most showed the oral sucker terminal, but in at least one it was sub-terminal. It is clear from an examination of such a series, as well as of living animals, that the apparent position of the oral sucker may depend on the position and state of contraction of the animal at the time of fixation.

Again, too much stress should not be placed on the relative sizes of the organs (oral and ventral suckers, pharynx, ovary and testes) and of their positions in the body. Descriptions of trematodes have often been given from one, or very few, specimens, and the condition of the animal (whether living, compressed, etc.) is seldom stated.

The absence of a receptaculum seminis was given by Lühe (1909) as one of the characters of the genus *Plagiorchis*. Olsen (1937) put *P. noblei* Park, 1936 into a new genus (*Plagiorchoides*), on the grounds that it had a receptaculum seminis, and in the same year, for this and other reasons, Mehra transferred it to *Neolepoderma* n.g. In 1939, Park suggested that if the possession of a seminal receptacle is to be a generic character the study of serial sections is absolutely necessary for diagnosis. In 1943, Baer (p. 43) stated that the presence of a seminal receptacle was typical of the genus *Plagiorchis*; this was quoted by Dollfus (1949, p. 437) without comment.

Yamaguti (1954) recorded *P. maculosus* from single specimens, from *Sturnia philippinensis* and *Passer montanus* from Macassar. The specimen from the first host was examined as a mounted specimen; there was a prepharynx and a small receptaculum seminis, which suggests that the identification is doubtful. On the other hand, the excretory system was studied in the second specimen, living. The excretory formula was given as  $2\{(2+2)+(2+2)\}=16$ . If all the flame cells were observed, the specimen could not belong to *Plagiorchis*, in which the flame cell pattern is  $2\{(3+3+3)+(3+3+3)\}$  (McMullen, 1937). However, flame cells are not easily seen, and with only one trematode to study, it is probable that some were missed.

The presence or absence of a receptaculum seminis seems thus to be a character of doubtful value. Without good serial sections, it would seem unwise to be dogmatic on its presence or absence in *Plagiorchis* species. It was not observed in the present investigation, although serial sections of two specimens (from swallow and wagtail) were studied.

The shape of the cirrus has been made a descriptive character, especially in the earlier accounts. Examination of a number of specimens of *P. maculosus* in the present investigation suggests that its apparent shape and size are variable, probably depending largely on the state of contraction of the animal, and the extent to which the cirrus is extruded. Fig. 1 shows a relatively broad cirrus, not greatly elongated; in most specimens in which it was everted, it was very narrow. One specimen (from a chick) showed the narrow cirrus projecting a



distance of 245  $\mu$  from the genital pore; in another (from a swallow), self-fertilization was observed, the cirrus being inserted well into the metraterm.

From records of *Plagiorchis maculosus* (details of which appear in the foregoing pages and in the tables) and from observations recorded in the present paper, the following amended diagnosis has been compiled:—

***Plagiorchis maculosus* (Rud.)**

**Diagnosis**—Mainly in insectivorous birds; also occasionally in other birds and in mammals. Snail host a lymnaeid; second intermediate host an insect with an aquatic larva.

Just under 1 mm.—4 mm. long; 0.4–1.25 mm. wide. Suckers about the same size, or oral sucker slightly larger than acetabulum. Acetabulum at end of first third of body length, or further caudad; well behind intestinal bifurcation. Prepharynx, if present, very short. Oesophagus present in cercaria; very short or apparently absent in adult. Intestinal caeca extend to near posterior end of body; wide, though not necessarily fixed in this position. Ovary smaller than acetabulum, or nearly equal to it; smaller than testes. Vitellaria extend anteriorly and laterally between pharynx and anterior border of acetabulum; posteriorly they extend to hind end of body, and fields may remain separate or may become confluent in mid-line.

The name *maculosus* was evidently given by Rudolphi for the testes and ovary—two or three “light spots” behind the ventral suckers which were especially characteristic for this worm. Other authors have attributed the name to the spination of the fore part of the body, and even to “the diffuse granules which remain from the eyes of the cercaria”.

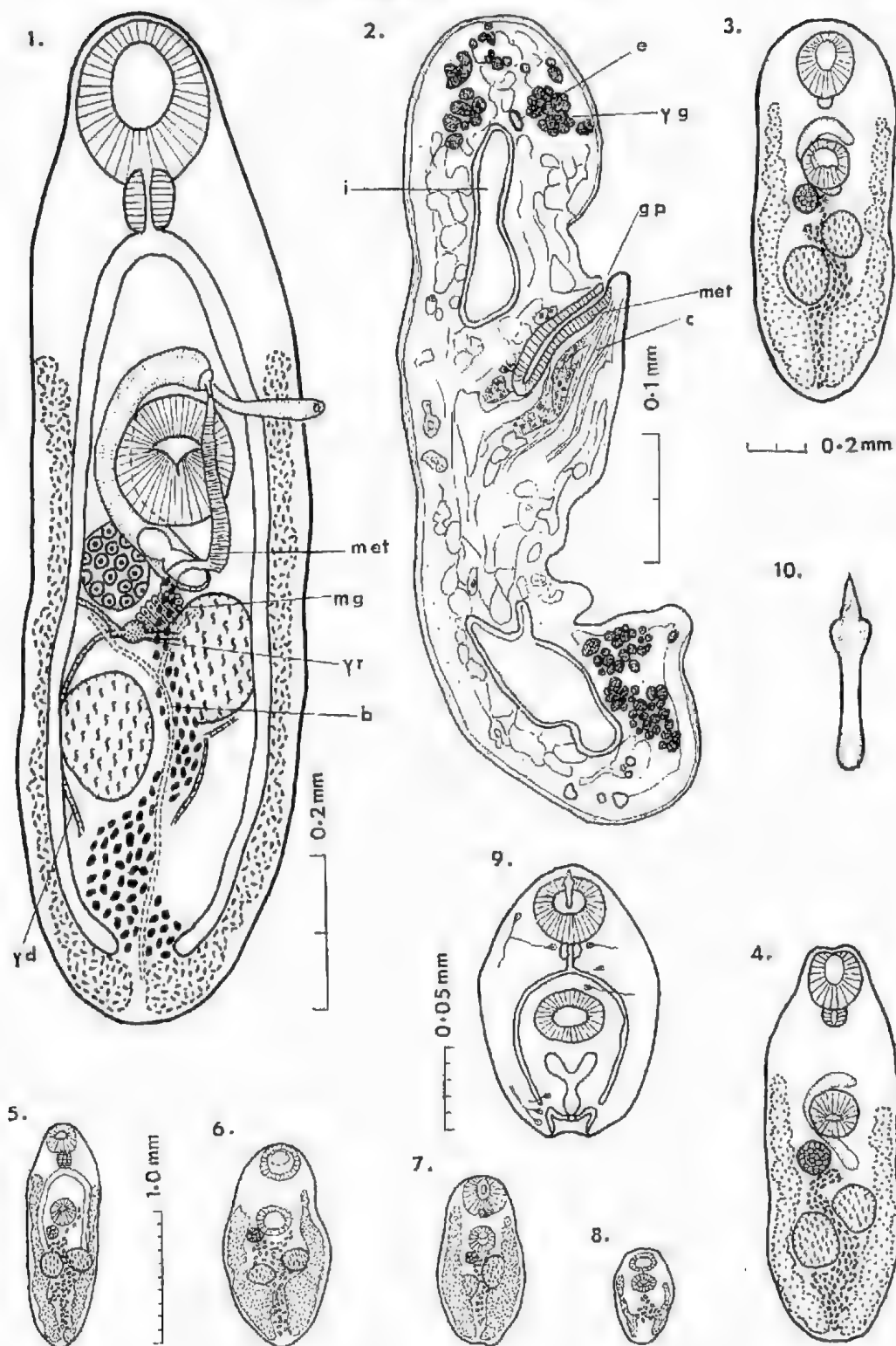
This trematode is now identified from South Australia from the swallow (*Hirundo neoxena*), the willy wagtail (*Rhipidura leucophrys*), the grey fantail (*R. flabellifera*), the magpie (*Gymnorhina hypoleuca*) and the white-browed babbler (*Pomatostomus superciliosus*). Measurements of the parasite from these hosts and from two chickens infected experimentally are given in Table 1. This table also includes measurements of two specimens of *Plagiorchis* from the Murray magpie (*Grallina cyanoleuca*). It is considered probable that they are *Plagiorchis maculosus*, but one specimen was not well preserved and does not look quite typical, and the other showed the ovary relatively larger than in specimens from other hosts. In the absence of further specimens from this host it is perhaps safer to identify these two trematodes as *Plagiorchis* sp.

Most of the specimens from *Pomatostomus superciliosus* did not resemble the typical *Plagiorchis maculosus* at first sight. They had been fixed, when alive, without any pressure; they were relatively short and stout, the anterior sucker was always subterminal, and the two suckers appeared to be placed close together, due to the curvature of the body. The skin was wrinkled and rather dark. In spite of this apparent dissimilarity it was not possible to name any essential differences, and sizes of organs conformed to the pattern of *P. maculosus* from other

**EXPLANATION OF FIGURES**

Figs 1–10. *Plagiorchis maculosus*. Figs. 1, 3, 4. Adults from swallow (March, 1956): N.B.—Variations in extent of vitellaria anteriorly, position of testes, oral sucker, etc.; 1, stained alum carmine. Fig. 2, T.S. Adult from wagtail, through genital pore. Figs. 5–8, Adults from babbler, 5–8 fixed alive, uncompressed; 5, fixed after death. Fig. 9, Cercaria; fixed specimen, position of some flame cells shown. Fig. 10, Stylet. Fig. 4 is to the same scale as Fig. 3. Figs. 6, 7, 8 are to the same scale as Fig. 5. b, bladder; c, cirrus; e, excretory canal; g.p., genital pore; i, intestine; met., metraterm; m.g., Mehlis' gland; yd., yolk duct; yg., yolk glands; yr., yolk reservoir.





hosts, although the distances between organs was generally reduced owing to the contracted state of the specimens. A few of the trematodes from the same collection had been fixed after death (Fig. 5); they were extended, were not dark in appearance, and were much more like *P. maculosus* from other hosts.

Of 8 specimens obtained experimentally from chicks, 4 were dissected when alive to obtain the eggs, so that measurements of only 4 are given. The suckers of the dissected specimens were measured in formalin and are included in the measurements.

## LIFE HISTORY

### Historical

As early as the 1850's there were suggestions concerning the life history of *Distomum maculosum*. Filippi's *Cercaria virgula* (named in 1837), the sporocysts of which were found in *Valvata piscinalis* and *Paludina impura*, and which encysted in perliids and some other aquatic insect larvae, was suggested as the larva of *Distomum maculosum*. Filippi and Diesing both referred to this. I have not had access to all of Filippi's papers, but in 1901 von Linstow mentioned that Filippi (1857) assumed, and probably rightly, that *D. maculosum* was the adult of these larval forms. Diesing (1858) stated that whether *Cercaria virgula* was the true larva of *Distomum maculosum* was still sub judice.

These two molluscs belong to different families, neither of which is closely related to the Lymnaeidae. The more recent work of Nöller and Ullrich (1927), Strenzke (1952), and the present investigation has shown a lymnaeid to be the snail intermediary for *Plagiorchis maculosus*. It seems likely that Filippi was identifying two different cercariae in his *Cercaria virgula*, and that neither of them was the cercaria of *Plagiorchis maculosus*.

Von Linstow described thick-walled, oval cysts in the neuropteran, *Drusus trifidus*. The contained metacercaria agreed so closely with *Distomum maculosum* that he considered it belonged to this species. He gave a figure of the metacercaria which showed ovary, testes and cirrus, but no uterus. The figure certainly suggests *Plagiorchis*, but from the description of the cyst, as well as its size, it seems unlikely that the species is *maculosa*.

Nöller and Ullrich (1927) reported that a xiphidiocercaria of the "Armata" group, from *Lymnaea stagnalis*, encysted in chironomid larvae. After adult and larval chironomids had been fed to canaries, finches and other small birds, trematodes identified as *Plagiorchis maculosus* were recovered. (35 mature trematodes were found in a canary on the 9th day.) Photographs of the various stages were given; though these do not show much detail, there is no reason (of appearance or size) to doubt that *P. maculosus* was the trematode involved. Although 7-week-old chicks were fed many larvae on successive days, none became infected. Nöller and Ullrich did not give a description of the sporocyst and cercaria, which they hoped to do later.

Strenzke (1952) gave an account of the life history and a description of the various stages of *P. maculosus* in Holstein. Sporocysts occurred in the mid-gut of *Radix auricularia*; the cyst was found as a natural occurrence in the larvae of *Chironomus thummi* and *Psectrotanypus varius*, and experimentally in larvae of the midge, *Chaoborus crystallinus*, and *Culex pipiens*. Two specimens of *Aidemomyne cantans* were infected (with 85 and 262 trematodes respectively) by feeding with infected chironomids.

### Experiments in South Australia

On 5th March, 1955, 2 of 55 *Lymnaea lessona* collected at Mannum (River Murray) were found to be infected with a small xiphidiocercaria. One of these snails was used for the following work.

The cercariae were found to encyst in mosquito larvae. From 8/3/55 the cercariae were put in small dishes each day with a batch of mosquito larvae. As the larvae and pupae died, or the adult mosquitoes hatched, they were fed to young chickens. Two of these chickens were later found to be infected with adult trematodes which were identified as *Plagiorchis maculosus*, and three were uninfected.\* Most of the larvae could have contained several cysts, and some of them possibly many. The attempted infections of these five chickens may be summarised as follows:—

- (1) Fed with 50 larvae; died 12 days after first, and 8 days after last larvae fed. No trematodes recovered.
- (2) Fed with 81 larvae, etc.; killed 49 days after first and 40 days after last larvae fed. No trematodes recovered.
- (3) Fed with about 250 larvae, etc.; killed 40 days after first and 25 days after last larvae fed. No trematodes recovered.
- (4) Fed with 227 larvae, etc.; died 13 days after the first and 3 days after last larvae fed. Six adult trematodes recovered.
- (5) Fed with 216 larvae, etc.; killed 21 days after the first and 14 days after last larvae fed. Two adult trematodes recovered.

The results from chicks (4) and (5) show that the trematodes had reached maturity within 13 days, and possibly less, after the cysts were ingested. (Stronczke fed finches with infected larvae and found trematode eggs in the faeces 7 days later. In one finch he recovered 85 trematodes, and in the second 262 specimens; the birds died as a result of the infection.)

The foregoing results suggest that chicks, not being the natural definitive host of *P. maculosus*, do not become infected unless given a massive dose of the cysts or that the infections are lost early.

The six *Plagiorchis maculosus* from chick (4) were left in saline from 4-8/4/55, and the eggs laid, with those dissected from three of the trematodes, were kept for a further seven days in boiled water, which was changed daily. No miracidia were seen during this time. On 15/4/55 the dish containing the eggs was put in a small infection tank with 12 young laboratory-raised *Lymnaea lessona*. One snail was completely disintegrated when found, 32 days later. Of the remaining snails, 10 died, in 39, 42, 43, 45, 48, 48, 49, 53, 53 and 55 days. Sporocysts were found in all, tailed cercariae being present in those which died in 43, 48, 49, 53 and 55 days. The twelfth snail was isolated, for the first time, 56 days after it had been placed in contact with the eggs, and was found to be emitting cercariae; it died 8 days later.

Eggs from the two *Plagiorchis maculosus* from chick (5) were left at room temperature for 17 days before being placed with 9 young *Lymnaea lessona*. It is not known whether the eggs were still viable. The snails died from 42 to 132 days afterwards, and none was infected.

Mosquito larvae were infected with cercariae from the infected snail. Only about 50 infected larvae were available to feed to two chicks when the snail died; the chicks were killed 7 weeks later, but were not infected.

Life history studies were also carried out with *Plagiorchis maculosus* from swallows, wagtails and babblers.

Eggs laid in normal saline were collected, and others were dissected from the adult trematodes. The eggs were kept in boiled water at room temperature during the week, and were examined daily when the water was changed. Over week-ends they were kept at 4° C.

\* Rees (1952, p. 93) noted that a mounted specimen of *P. (P.) maculosus* (from a turkey) in the Natural History Museum showed no differences from the same species recovered from the normal bird hosts.

*Lymanaea lessoni* reared in the laboratory were used. Dead snails were dissected under binocular microscope. Results are summarised below; the result "apparently negative" means that larval stages were not seen. (Records of deaths of snails which were too disintegrated for examination are not given.)

#### ***Pomatostomus superciliosus***

Eggs laid 1-3/3/56; dissected 7/3/56; put with snails 9/3/56.

One snail apparently negative in 14 days.

Four snails had sporocysts, but no free cercariae, at 27, 33, 34 and 39 days.

#### ***Hirundo neoxena***

Eggs dissected from 4 trematodes 14/3/56; put with 12 snails 22/3/56.

Three snails apparently negative when they died in 15, 21 and 21 days.

1 snail had sporocysts at 21 days.

One snail had numerous sporocysts and a few motile cercariae at 39 days.

One snail omitted cercariae when tested at 40 days. (It had not done so when previously isolated at 26 days.) Died at 43 days.

#### ***Rhipidura leucophrys***

Eggs dissected from 6 trematodes 15/3/57; and from 2 trematodes 16/3/57; put with snails 22/3/57.

Three snails were dead and apparently negative at 17, 24 and 36 days.

Remaining 7 snails all gave abundant cercariae when first isolated at 45 days; (These snails died at 45, 46, 47, 48, 50, 69 and 73 days.)

The above results show that the shortest time observed for the production of cercariae was 39 days (in *L. lessoni* subjected to infection in March), and it seems probable that this was not much longer than the actual time taken for infections at this time of year.

Snails other than *Lymanaea lessoni* have also been used in experiments on a number of occasions. In the earlier experiments the trematode eggs were put with the snails within a day of being dissected from the trematode; although all results were negative, this cannot be regarded as significant, in the absence of *L. lessoni*, since it is probable that the eggs would not be infective for several days after being laid or removed from the adult. However, in March 1956, 8 *Amerianna* sp. did not become infected in 21, 25, 28, 36 and 64 (4) days, in the same tank in which 3 *Lymanaea lessoni* were infected with *Plagiorchis maculosus* from the swallow; and in the same month, 4 *Amerianna* sp. were uninfected after 56 and 62 (3) days, in the same tank in which 4 *Lymanaea lessoni* showed sporocysts as early as 27 days.

### **OBSERVATIONS ON STAGES IN LIFE CYCLE**

#### ***The Egg and Miracidium***

The eggs averaged about  $30\ \mu \times 19\ \mu$ , but the length varied from 29-31.5  $\mu$ , and the breadth from 17-20  $\mu$ .

There is no evidence as to the hatching of a miracidium. If there is a free-swimming miracidium, the experiments suggest that hatching does not occur earlier than 7 days after the egg is laid. Strenzke did not find a miracidium. It seems probable that hatching follows ingestion of the eggs by the snail host.

It was not possible to make out any detail in viable eggs under ordinary high power, though the miracidium was seen to move within the shell several days after the eggs were laid.

### The Sporocyst

The sporocysts were small and contained only a small number of cercariae. They corresponded in appearance with that shown in Strenzke's photograph. Formalinised specimens measured up to  $0.8 \times 0.14$  mm. in snails infected 46 days previously; while in snails infected 39 days previously the largest sporocyst observed was  $0.54 \times 0.14$  mm. Strenzke's figures were  $0.7-1.0$  mm.  $\times$   $0.20-0.25$  mm.; his measurements were probably of living material and in newly killed snails. In the present investigation sporocysts were not examined until the snail was found dead, and under these circumstances most of the cercariae have escaped from the sporocyst, leaving it thinner in appearance. As shown by the dimensions above, the size is probably also dependent to some extent on age.

### The Cercaria

The cercaria has been found as a natural infection of *Lymnaea lessona* from the River Murray swamps, from Wellington to Morgan, in 73 of over 8600 of the snails examined between April 1937 and March 1938 (0.85 per cent. infection). It has also been found in a small pond in a garden at Tailem Bend in 37 of 1700 *L. lessona* since 1943 (3.3 per cent.).

The cercariae emerged normally in the early morning (before 9.30 a.m.). Their activity diminished noticeably during the morning, and by afternoon only a few were still swimming; the remainder were still alive, but lying at the bottom of the tube. About 4 p.m. some cercariae were put at  $5^{\circ}$  C., and 24 hours later, when brought out to room temperature, they swam quite actively.

Measurements of cercariae collected at different times from naturally infected individual *L. lessona*, as well as from *L. lessona* which had been experimentally infected with eggs from different bird hosts, are given in Table 3. They were fixed by adding an equal volume of boiling 10 per cent. formalin to the water in which they were swimming. It will be noticed that there is a slight variation in size range for the cercariae from individual hosts. This is regarded as being of no significance, considering the number of variable factors involved. The cercariae were deliberately chosen for measurement from those which had been fixed in the most extended position. The time of day at which they are killed is likely also to affect the state, whether extended or otherwise.

Strenzke gave the following measurements for cercariae "killed by slight heating". Length 250-300  $\mu$ ; breadth 120-140  $\mu$ ; diameter of oral sucker 60  $\mu$ , ventral sucker 36  $\mu$ .

The size of the stylet in this particular cercaria is somewhat variable. The stylet is also rather fragile in formalin, and splits lengthwise under even moderate pressure of a coverslip. It was difficult with almost all the formalinised material to find an adequate number of stylets which were in good condition and also in a suitable position to be measured accurately. The actual range for length of formalinised stylets was 21.5-24.8  $\mu$ ,\* in the comparatively small number measured, while for living specimens it was 24.3-28.9  $\mu$ . In all cases measurements on stylets of living cercariae were greater (by 1.2-3.8  $\mu$ ) than on stylets of formalinised cercariae from the same snail. Strenzke gave a measurement of 25-27  $\mu$ , and this would probably be the normal range in our material, though larger and smaller specimens do occur. Precise length of stylet should not be used as a diagnostic character for *Plagiorchis maculosus*.

The stylet is shapely, 6.7  $\mu$  across the shoulders, the main stem being of fairly uniform diameter except near the base, where it increases slightly, being about 4.1-4.5  $\mu$ . The base itself is rounded and has no plug.

\* In 1951 we reported (Johnston and Angel, 1951, p. 54) that the only common xiphidocercaria found by us in *Lymnaea lessona* was a form with stylet 24  $\mu$  long. This is the cercaria now identified as the larva of *Plagiorchis maculosus*.

The whole surface of the body is beset with rows of tiny spines. The acetabulum is situated in the posterior half of the body.

There is an obvious pharynx, but the rest of the alimentary system is not easily seen. Sometimes there appeared to be a slight prepharynx; if this is indeed present (and not an artefact), it is, as was noted for the adult, very short. There is a short oesophagus; this, and the alimentary caeca, were very narrow when seen at all.

The excretory system is very difficult to elucidate. Treatment with intra vitam stains such as basic fuchsin in saline, improved it only slightly. The gland and cystogenous cells which occur throughout the body are sometimes extremely opaque and murky in appearance, and it is impossible to see through them. The bladder itself can generally be seen quite clearly. It is Y-shaped, and in life is continually changing shape; the upper part of the stem sometimes contracts so strongly that the bladder appears to consist of two parts, the posterior one rounded, the anterior one with short, wide arms in the form of a V. McMullen (1937) showed the main excretory vessels arising from the tips of the arms of the bladder for *Plugiorchis* spp. In the material examined here it was almost impossible to come to a decision. At one time the vessels would appear to arise terminally, at another it would seem equally certain that they were sub-terminal. It was pointed out for *P. jaenschi* (Johnston and Angel, 1951) that the twisting of the main and accessory tubes, with other factors, made the supposed point of entry of the main vessels into the bladder a matter to be regarded with some reserve. The anterior and posterior collecting vessels diverge from the main excretory tube at a point level with the middle of the acetabulum, but, of course, lateral to it. Beyond this, little detail of the excretory system was seen, with the exception of odd flame cells, as shown in Fig. 9. Refractile granules are scattered throughout the body. They are not abundant, as in some cercariae; the size is variable, some being very small. The gland cells occur in about 3 rows from just anterior to the acetabulum to midway between it and the pharynx. Laterally, and also posteriorly to the acetabulum, the body is filled with cells which stain with neutral red and faintly with methylene blue. They may be only cystogenous cells, but if this is so it seems strange that the anterior part of the body is quite free of them. These cells stain a uniform pale pink with neutral red, some of the nuclei showing a bright red. Without stain the cells appear greenish, finely granular, with clear nuclei. In the more darkly stained specimens the bladder shows up clearly as an unstained area.

The ducts of the gland cells, which showed only in the pre-acetabular region, were greenish, finely granular, and seemed to be only about three in number on each side.

The genital primordium shows after staining with neutral red as a mass of small undifferentiated cells in the region of the future cirrus complex.

#### *The Cyst*

Cercariae encysted readily in mosquito larvae.

The cysts were found most commonly in the head and the abdomen, and a few were found in the thorax. In the pupa it was difficult to determine the exact site of infection. One larvae which was examined after 48 hours with the host snail contained 117 cysts—29 in the head, 3 in the thorax, and 85 in the abdomen.

The cysts resembled those figured by Nöller and Ullrich (1927) and photographed by Strenzke (1952).



They were small, rounded and fairly thin-walled; the dark concretions in the excretory bladder were a regular and characteristic feature. The bladder showed through the cyst wall as a very dark Y or V shape, in which the arms and tail stem were short and stout.

Cysts one day old measured about  $90\text{--}105\ \mu \times 90\text{--}98\ \mu$ , and three cysts of 20 days old (which were the largest of about 80 measured) were  $106\text{--}120\ \mu \times 106\text{--}113\ \mu$ . The average size of 80 cysts, most of which were from 1-8 days old, was  $108\text{--}100\ \mu$ .

Strenzke recorded the cysts as being usually round, seldom oval; an average of 100 cysts  $128\ \mu$  in diameter, the range  $102\text{--}150\ \mu$ .

The cyst described by von Linstow which was mentioned previously in this paper, was thick-walled, oval and measured  $440 \times 300\ \mu$ . As stated above, this was probably another species of *Plagiorchis*. According to von Linstow, Filippi gave the cyst diameter as  $190\ \mu$ .

The natural secondary host is probably a chironomid, though no doubt the cercaria sometimes utilizes mosquito and other insect larvae under natural conditions. Chironomid larvae were not available in the laboratory at any of the times that infections were being tried.

Animals used in trial infections, from none of which were cysts recovered, were the crustaceans, *Daphnia* sp., shrimp (*Paratya australiensis*), yabbie (*Cherax destructor*), amphipod (*Chiltonia subtenuis*); the molluscs *Lemanea* sp., *Planorbis isingi*, *Lymnaea lessoni*; 2 leeches; the fish *Gambusia affinis*, and tadpoles (*Limnodynastes* sp.).

The only other xiphidiocercaria which has been found as a parasite of *Lymnaea lessoni* in South Australia, *Cercaria Plagiorchis jaenschi* Johnston and Angel, 1951, is very similar in size and appearance to *C. Plagiorchis maculosus*. It is distinguishable in fresh material, without detailed microscopical examination, only by the size of the stylet, which is noticeably larger ( $34\ \mu$ ) in *C. Plagiorchis jaenschi*. The gland cells are more extensive in *C. Plagiorchis maculosus*. The normal secondary intermediate host of *P. jaenschi* was thought to be the crustacean, *Cherax destructor* (in which encystation took place readily); in *Plagiorchis maculosus* encystation occurs in insect larvae, but apparently not in crustaceans.

*Plagiorchis maculosus* has now been recorded from a large number of birds, most of which are insectivorous, and from the rodent, *Citellus musicus planicola*. It was found in 50 per cent. of the *Citellus* examined by Schulz (1932) in what was apparently a fairly wide survey. It appears that *Plagiorchis maculosus* has no great specificity for its adult host, though the second intermediate host is very restricted. It seems likely that many species of *Plagiorchis* have been described as new largely because they occurred in unrelated hosts, and an examination of the types may indicate a large number of synonyms of *P. maculosus*.

I have been able to examine types of *P. clelandi* Johnston, 1917, and *P. spatulatus* Johnston, 1917 (Australian Museum W.435 and W.434 respectively), and was unable to find any points by which they could be separated from the Australian specimens of *P. maculosus* I have examined, and measurements of which are given in this paper.

Johnston stated that *P. clelandi* was more closely related to *P. maculosus* (Rud.) than to any other species. It differed mainly in the arrangement of the fields of the yolk glands, which in the Australian species never extended as far forwards as the fork of the intestine, and always remained separate in the posterior region. In the type specimen the follicles of the yolk glands have taken up the stain more deeply in some parts than in others; close examination of the



dorsal surface shows that some follicles do extend between the two main fields and that there are even one or two follicles right in the median line. The testes are bigger than in most specimens examined, but I do not consider this justifies the placing of the species in the variety *analis*.

The inclusion of *P. spatulatus* as a synonym of *P. maculosus* means that the lower range for size of this species must be extended. However, there seem no other differences by which to separate the two species. According to Johnston, *P. spatulatus* resembled *P. maculosus* more closely than any other species. He separated *P. clelandi* from *P. spatulatus* on a number of points, but especially in the extent of the yolk gland fields, which extended further forward, were more lateral in front of the testes and extended further in towards the middle behind them in *P. spatulatus*.

Johnston (p. 248) noted that whereas *P. clelandi*, *P. maculosus*, *P. nishetii* were from passerine birds, *P. spatulatus* occurred in one of the Motacillidae (*Anthus australis*). He did not compare it with *P. notabilis* Nicoll, 1909, which was from *Anthus obscurus* and *Motacilla flava*. Nicoll gave as the chief diagnostic features of the species the short cirrus-pouch and the forward position of the ovary. The figure is presumably drawn from the one adult specimen from *Anthus obscurus*, which was described first, and "the main features of difference in the specimen from *Motacilla*" were then indicated. From the figure, the anterior part of the worm is contracted, and this seems enough to explain the apparent forward position of ovary and, with the fact that the cirrus is everted, the shortness of the cirrus pouch. Yamaguti (1954, p. 337) noted that the posterior extent of the cirrus pouch being subject to considerable variation in the members of this genus, does not constitute by itself a decisive criterion in specific determination.

In 1954, Horton-Smith and Long recovered 35 trematodes from the small intestine of a pullet from Scotland, which were identified as *Plagiorchis notabilis* by Dr. S. Prudhoe of the British Museum (Natural History). The metacercariae were found encysted in the larvae of chironomid and other flies.

I can find no record of where the type is deposited. It seems probable that *Plagiorchis notabilis* is a synonym of *P. maculosus*.

Nicoll (1909) described from Townsville, Queensland, *Lepoderma nishetii* from *Chibia* (*Dicrura*) *bracteata*. Nicoll's figure is not very detailed, and he stated that the two specimens, from which the description was made, were "somewhat macerated". Nicoll did not designate a type, nor state where the specimens were deposited, but Mr. A. J. Bearup, of the Australian Institute of Tropical Medicine, has sent me two spirit specimens which are obviously the ones from which Nicoll gave his description (A.I.T.M. No. 121). Mr. Bearup tells me that the label is in Nicoll's handwriting; the details are similar to those given in the paper. One worm was in pieces, the other very dark. Though treatment with trisodium phosphate improved the intact worm, it was not in good enough condition to enable any real description to be given.

It is not possible to say that this is a synonym of *Plagiorchis maculosus*, though the differences (from the description and the figure) may well be attributable to the poor condition of the specimens. Nicoll did not name any differential characters for the species.

Yamaguti and Mitunaga (1943) stated that it seemed probable that *P. orientalis* Park (1939) from the Korean *Hirundo daurica nipalensis* was identical with *P. maculosus*. Park had distinguished it from var. *citelli* by (1) the vitellaria being confluent dorsally, and (2) the fact that the cirrus sac extended only to the posterior margin of the acetabulum.

VARIETIES OF *PLAGIORCHIS MACULOSUS*

In 1928 Skrjabin described *P. maculosus* var. *anatis*, from 1 specimen found in 1 of 2 ducks (*Casarca casarca*) from Transbaikalia. A characteristic difference between this variety and the typical *P. maculosus* was the structure of the vitelline follicles which, in the variety, were rather small individually but very closely placed, and in the typical form "plus gros, plus grands" and less thickly distributed. From Skrjabin's figure, the most obvious feature is the size of the testes, which appear relatively huge. The measurements given were 0.4 mm. diameter for each, which is appreciably larger than in any specimen previously recorded, or in any examined in the present collection. The size of the eggs, also,  $36 \times 22 \mu$ , is somewhat greater than in other *P. maculosus*.

The condition of the animal, whether living, dead, compressed, etc., was not mentioned. To my knowledge, this variety has not been recorded since it was described.

Massino, in 1929, included a description of Skrjabin's specimen. His paper has an obvious mistake in labelling. His Fig. 9 which was labelled *P. maculosus* var. *anatinus*, corresponds to Skrjabin's Fig. 2 of *Plagiorchis potanini*, while his Fig. 8, called *P. potanini*, corresponds with Skrjabin's Fig. 1 of *P. maculosus* var. *anatis*.

Mehra (1937), who had apparently seen Massino's figures and not Skrjabin's, transferred *Lepodermis maculosus* var. *anatinus* to a new species, *L. (Multiglandularis) russii* on the grounds that it did not belong to the subgenus *Plagiorchis*, as did *P. maculosus*. The species *P. russii* is thus invalid, being a synonym of *P. potanini*.

*P. maculosus* var. *citelli* was described by Schulz in 1932 from the rodent *Citellus musicus planicola*. Schulz stated that it did not really differ from the typical *Plagiorchis maculosus* described in 1802, or from Skrjabin's *P. maculosus anatis* (from a duck); on the other hand, it was very near to *P. papouei* Palappestow which was described from a dog and was later found by Skworzow in a pig. Schulz placed it as a separate subspecies because of its host, but thought it possible that when more material was available and the biology of the parasite better known, it might be necessary to synonymise these previously mentioned forms.

In 1939 Yamaguti described *P. maculosus motacillae* from *Motacilla cinerea caspica*. He stated that it differed from the closely related *Plagiorchis notabilis* Nicoll, 1909, *P. spatulatus* Johnston, 1917, and *P. maculosus* (Rud.), in the posterior position of the testes. From his figure, the anterior border of the anterior testis is at exactly the middle of the body. The posterior testis does appear to lie nearer to the posterior end of the body than is usual in *P. maculosus*, but this is partly due to the large size of the testes, and partly perhaps to the contracted state of the body, which is evident from the figure in the anterior region. Yamaguti did not mention *P. maculosus anatis*, in which the testes are large and extend almost as far posteriorly as in *P. maculosus motacillae*. There seems no valid distinguishing feature between these two varieties. If the large size of the testes is a uniform character, the variety *anatis* should stand, with var. *motacillae* a synonym. However, *anatis* was described from a single specimen, and Yamaguti's *motacillae* was described from only 3 specimens, 1.0-1.5 mm. long, in which the range of size for the testes was  $0.15-0.31 \times 0.15-0.28$  mm., while the suckers varied only slightly. The size of the testes may be variable, or apparent differences may be attributable to treatment or fixation.

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TABLE 1.  
*PLAGIORCHIS MACULOSUS* FROM BIRDS IN SOUTH AUSTRALIA.

N.B. The two specimens from *Grallina cyanoleuca* are identified only as *Plagiorchis* sp. (See text p.268.). The range of measurements for length and breadth is given; the size of organs is given as averages. Length of organs given first, width afterwards. The number of specimens in which it was possible to measure the organs is given in brackets. All specimens fixed in formalin.

Date	No. of birds included	Host	Locality	No. measured	Fixation	Length mm.	Breadth mm.	Oral Sucker mm.	Ventral Sucker mm.	Anterior testis mm.	Posterior testis mm.	Ovary mm.
15.9.48	1	<i>Hirundo neozena</i>	Tailum Bend	6	Flattened	1.5-3.2	.50-.85					
5.3.56	6	<i>Hirundo neozena</i>	Wellington	10		0.9-1.8	.27-.71	.23 × .20 (6)	.19 × .21 (6)	.15 × .15 (3)	.18 × .15 (3)	.12 × .11 (3)
18.9.40	1	<i>Rhipidura leucophrys</i>	Tailum Bend	10	Flattened	1.7-2.5	.61-.81	.26 × .26	.26 × .25	.25 × .21	.28 × .22	.17 × .17
2.3.56	1	<i>Rhipidura leucophrys</i>	Morgan	2		0.97-1.1	.33-.37	.18 × .18	.15 × .15			
11.3.57	5	<i>Rhipidura leucophrys</i>	Tailum Bend	11		1.3-2.6	.48-.77	.21 × .23	.22 × .20	.22 × .20	.26 × .21	.16 × .16
15.10.37	1	<i>R. flabellifera</i>	Tailum Bend	1		1.5	.60	.20 × .22	.20 × .19	.19 × .20	.22 × .17	.12 × .12
8.3.44	1	<i>R. flabellifera</i>	Tailum Bend	1		1.4	.53	.20 × .20	.22 × .20	.23 × .20	.26 × .18	.18 × .14
27.10.48	1	<i>R. flabellifera</i>	Tailum Bend	5		1.7-2.9	.67-.76	.23 × .25	.26 × .24	.35 × .26 (3)	.42 × .30 (3)	.24 × .21 (3)
23.2.42	1	<i>Gymnorhina hypoleuca</i>	Tailum Bend	1		1.7	.55	.25 × .25	.22 × .22	.20 × .18	.22 × .17	.16 × .17
28.2.56	4	<i>Pomatostomus superciliosus</i>	Morgan	6	Fixed, when alive, without pressure	0.8-1.5	.37-.80	.20 × .22	.18 × .19	.14 × .14	.14 × .16	.11 × .12
7.4.55	2	Chicken (Experimental)		7	Fixed after death	1.1-1.9	.32-.57	.19 × .19	.17 × .17	.13 × .11	.13 × .11	.11 × .09
26.2.40	1	<i>Grallina cyanoleuca</i>	Tailum Bend	4		1.6-2.4	.60-.63	.25 × .25 (7)	.22 × .20 (7)	.24 × .20 (3)	.25 × .20 (3)	.19 × .19 (3)
1.6.40	1	<i>Grallina cyanoleuca</i>	Tailum Bend	1		2.0	.75	.33 × .37	.30 × .28	.24 × .20	.24 × .18	.28 × .22
			Tailum Bend	1		1.6	.47	.27 × .26	.19 × .19	.22 × .17	.22 × .17	.14 × .12

TABLE 2.

RECORDED DIMENSIONS AND HOSTS OF *PLAGIORCHIS MACULOSUS*.

Measurements in inverted commas estimated from drawings, or by converting "lines" into millimetres.

Measurements, in mm., are given to nearest decimal place; in some cases, e.g. for *P. orientalis*, approximate measurements are estimated.

Date	Author	Name	Hosts	No.	Fixation	Length	Breadth	Oral Sucker	Ventral Sucker	Anterior Testis	Posterior Testis	Ovary	Eggs	
						mm.	mm.						Length microns	Breadth microns
1902	Rudolphi	<i>Fasciola maculosa</i>	<i>Hirundo rustica</i>	—	—	"2.1"	"0.5-0.7"							
1902	Braun	<i>Plagiorchis maculosa</i>	<i>Hirundo rustica</i>	1	—	"2.66"	"0.8"							
1909	Lühe	<i>Plagiorchis maculosa</i>	<i>Riparia riparia</i> <i>Delichon urbica</i> <i>Apus apus</i> <i>Hirundo rustica</i> <i>Caprimulgus europaeus</i>			2.0-2.5	0.5-0.7	.20-.30	.15-.20					
1928	Skrjabin	<i>P. maculosus</i> var. <i>annalis</i>	<i>Casarca casarca</i>	1		2.2	0.75	.23 × .25	.25	.40 × .40	.40 × .40	.22 × .24	36	22
1932	Schulz	<i>P. maculosus</i> var. <i>citelli</i>	<i>Citellus musicus planicollis</i>			2.0-2.6	.96-1.00	.25-.30 × .26-.28	.30-.31 × .28-.32	.29-.25 × .28-.26	.33-.27 × .28	.29-.27 × .25-.27	30-34	19
1935	Yamaguti	<i>P. maculosus</i>	<i>Hirundo rustica gutturalis</i>	3	—	1.60-1.92	.57-.70	.20-.25	"same"	.25	.25	.16-.22 × .14-.16	32-36	20-24
1939	Yamaguti	<i>P. maculosus</i>	<i>Hirundo rustica gutturalis</i> <i>H. daurica nipalensis</i>	?	Fixed in acetie sublimate under slight cover-glass pressure.	1.6-3.9	.56-1.25	.20-.34	.20-.35	.22-.50	.18-.43	.16-.34 × .13-.30	30-39	18-24
1939	Yamaguti	<i>P. maculosus</i> var. <i>motacillar</i>	<i>Motacilla cinerea caspia</i>	3	—	1.0-1.5	0.4-0.6	.16-.18	.13-.15	.15-.31	.15-.28 (subglobular)	.10-.19 rounded	30-33	18-19
1943	Yamaguti	<i>P. maculosus</i>	<i>Hirundo rustica gutturalis</i>	6		1.6-1.8	.52-.60	.22-.25 × .21-.25	.19-.24 × .20-.25	.20-.25	.20-.26	.15-.18 × .17-.20	30-34	18-21
			<i>Parus alricapillus restrictus</i>	4	—	2.2-2.5	.75-1.00	.19-.30 × .20-.30	.21-.30 × .21-.30	.21-.35	.20-.35	.20-.28 × .26-.29	33-39	18-21
1946	Callot	<i>Lepoderma maculosum</i>	<i>Apus apus</i>	1	Living	2.5	0.80	.30	.32	.34 × .30	.35 × .26	.30		
				1	Same specimen fixed.	2.35	0.85	.30	.25				30-32	20
1952	Strenzke	<i>P. maculosus</i>	<i>Aidemasyne cantans</i>	"30"	mature, with eggs with only few eggs	1.6-2.0 1.1-1.4	0.5-0.8 0.1-0.2						34-37	21-23
1909	Nicoll	<i>P. notabilis</i>	<i>Anthus obscurus</i>	1	—	1.6	.57	.20 × .18	.16 × .16	.25 × .16	"About same"	.16 × .12	31	19
			<i>Motacilla flava</i>	1		1.4	—	.17 × .16	.14 × .13	.19 × .15	.17 × .15	.11 × .10	31	21
1914	Nicoll	<i>P. nisbetii</i>	<i>Chibia bracteata</i>	2	"Somewhat macerated"	1.25	.40	.22 × .24	.15 × .14	.1 long "Elongate oval"	"Slightly larger"	.11 × .11		
1916	Johnston, S. J.	<i>P. spatulatus</i>	<i>Anthus australis</i>		Balsam mount	.80-.99	.35-.39	.16	.13	.14 × .12	.14 × .12	.08	29-33	17
1916	Johnston, S. J.	<i>P. clelandi</i>	<i>Petrochelidon ariel</i>	1	Balsam mount	.2.2	.65	.29 × .25	.25	.31 × .29	.37 × .29	.17 × .23	30-33	17-22
1939	Park	<i>P. orientalis</i>	"Swallow"	3	—	1.5-1.7	.69-.75	.23 × .23	.23 × .24	.20 × .26	.28 × .22	.16 × .20	28-34	14-19

\* Type specimens. In the case of *P. spatulatus*, the range of length and breadth is given for an unspecified number of worms; the type was 0.99 mm. × 0.39 mm.

TABLE 3.

DIMENSIONS OF THE CERCARIAE OF *PLAGIORCHIS MACULOSUS*

Date	Host, Locality	Length		Breadth		Oral Sucker (Average) microns	Ventral Sucker (Average) microns
		Range microns	Average microns	Range microns	Average microns		
17.2.41	From 4 <i>Lymnaea</i> Tailern Bend	151-236	180	66-106	86	36 × 36	25 × 28
5.1.51	From 1 <i>Lymnaea</i> Mannum	124-157	141	84-102	94	38 × 41	28 × 31
5.1.51	From 1 <i>Lymnaea</i> Mannum	135-168	150	78-97	87	38 × 38	26 × 30
9.1.51	From 1 <i>Lymnaea</i> Tailern Bend	109-158	132	83-107	91	35 × 38	26 × 30
5.3.55	From 1 <i>Lymnaea</i> Mannum	150-236	175	81-107	94	41 × 41	30 × 34
28.5.55	(Chicken)	145-191	172	81-97	91	41 × 40	28 × 33
2.5.56	( <i>Hirundo neoxena</i> )	119-147	132	74-109	86	33 × 36	26 × 30
7.5.57	( <i>Rhipidura leucophrys</i> )	142-190	167	64-87	76	40 × 35	28 × 30

NOTES: All measurements in microns, of 10 specimens fixed in boiling 10% formalin.  
 The last three sets of measurements were from *Lymnaea* which had been infected experimentally with egg of *Plagiorchis maculosus* from the given hosts.



# ON *BETTONGIA CUNICULUS* OGILBY, 1838 (MARSUPIALLA)

BY *H. H. FINLAYSON*

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[Read 9 October 1958]

### SUMMARY

An analysis of the characters of a small series of *Bettongia cuniculus* Ogilby from Tasmania is made for comparison with mainland forms of *B. penicillata* Gray and *B. lesueuri* Quoy and Gaimard.

This species was formerly regarded as exclusively Tasmanian in occurrence, and its supposed insularity has tended to minimise somewhat the importance in practical taxonomy of several areas of vagueness and conflict in its description. Since Brazenor (1950) confirmed the Victorian status of the species, as originally claimed by Hall and Kershaw (1917), the necessity for clarifying its distinctions from the well ascertained mainland species has sharpened. A small series of four skins and eleven skulls personally collected in the district of the upper Macquarie River in eastern Tasmania, while inadequate for complete re-description, has prompted the examination summarized below, which may reduce these uncertainties. The comparisons instituted are chiefly with *B. penicillata ogilbyi* of South and Western Australia, and *B. lesueuri* of South and Central Australia; *B. gaimardi* and the eastern form of *B. penicillata*, which may be closer to *B. cuniculus*, have not been available locally.

### EXTERNAL CHARACTERS

Rhinarium very coarsely granular, much more so than in *B. penicillata* and *B. lesueuri*, but its upper margin with a backward and upward directed spur, as in the former.

Facial vibrissae weak in comparison with body size, the mysticals reaching 37 mm. as a maximum; the lower rows are white, the upper brown and none black. The supra orbitals may be longer than the mysticals (max. 42 mm.) and are pale brown, as are the genals also with length ranging from 29-36 mm. Black eyelashes are present on both upper and lower eyelids, but are weakly developed. On the lower border of the orbit a crescent of stout black bristles is developed, the longest 17 mm., and there is a similar but weaker series on the upper border; the development of these bristles is very strong in *Aepyprymnus* and falls off in the order *B. cuniculus*, *B. penicillata*, *B. lesueuri*. Submentals and interramals were not checked in the fresh material and are incomplete in the skins; the interramals present are two in number, silvery white and from 12-17 mm. long, springing from a common median site about 20 mm. posterior to the mid point of the lower lip.

The manus is much stouter than in *B. penicillata*; the digital formula is  $3 > 4 > \text{or} = 2 > 5 > \text{or} = 1$ ; the 2nd digit is shorter relative to the 3rd than in that species and the 4th is much stouter than the 2nd, and its claw is both stouter and longer, so that its general size superiority over the 2nd is more decided than is indicated by the formula. The claws are straighter and wider at the base and taper more to the point in a superior view than in *B. penicillata* in which they are nearly parallel sided, when seen from above; 3rd claw (maximum) 15.5 mm.; 4th claw 13.5 mm.

Pes stout with short blunt digits and nails; the plantar surface is completely naked as in *Aepyprymnus*, therein differing from *B. lesueuri* and *B. penicillata* in which it is more or less completely haired in the young animal; in colour of integument it is dusky though less so than in *B. penicillata*; granules 14 per cm. under the midmetatarsus, as in *B. lesueuri*, coarser than in *B. penicillata*; nails white.

The tail is stout and in the single example measured has the length about 106 per cent. of that of head and body, as in the Central Australian *B. lesueuri*, and relatively longer than in *Aepyprymnus* and *B.p. ogilbyi*.

### DIMENSIONS

The following figures give the dimensions in mm. of an adult male (P<sup>1</sup>M<sup>1</sup>) measured in the flesh: head and body, 325; tail, 345; chest girth, 180; manus length, 28; nail of 3rd digit, 16; pes, 121; 4th toe, 57; nail of 4th toe, 14.4; ear, 43 × 23; rhinarium to eye, 46; eye to ear, 28; eye (intercanthal), 15; weight, 1590 g.

### PELAGE

The texture of the coat is intermediate — crisper than in *B. lesueuri*, much softer than in adults of *B.p. ogilbyi*; it is longer than in either but not denser as to underfur. There is a strong overlay of guard hairs over all the dorsum, except on the nape, where the fur is longer and looser and ruff-like. General colour a pale, strongly grizzled brownish grey, with the head and tail somewhat darker, and the limbs decidedly lighter than the body. In two examples a well-marked pale hip stripe is present, contrary to Thomas's statement.

The composition of the pelage is similar to that of *B. lesueuri* and *B.p. ogilbyi*, but somewhat more complex. Mid-dorsally the main pile of underfur is from 20-23 mm. long; the basal three-quarters of which is Ridgway's blackish plumbeous, a subterminal band of 3-4 mm. wood brown and the points clove brown, not black. Guard hairs vary in length from 27-30 mm. and show some variation in the number of colour bands and their length. The more numerous and stouter have the normal four bands as in the above named species, i.e. 20 mm. plumbeous, 4 mm. sepia, 4 mm. ivory shading to buff and sepia, and 5 mm. sepia. The minority are more slender and the ivory band is split into two by interposition of a very narrow, dark sepia band. There is also a sparse representation of a 3rd category of very stout, all dark guards, reaching 36 mm. and medium sepia. The resulting external colour dorsally is a pale, strongly grizzled drab — the pallor due largely to the blend of ivory and ash buff, which is not much darkened by the overlay of weak sepia points. The colour is warmer on nape and crown and slightly paler on rump. *Ventrum*, basally deep plumbeous, externally greyish white washed lightly with yellow buff. There are two piles — the underfur of 23 mm. ca. in which the basal half is plumbeous and the rest creamy white and the sparse guard hairs of 30 mm. in which the basal 2/3ths is plumbeous, median 1/3th sepia and terminal 1/3th creamy white. The *sides* are slightly paler than the dorsum, the subterminal colour being reduced to tulleil buff as on the rump. The *head* is slightly darker than the mid back with a small variable area on the muzzle bistre. The *ear* backs are well furred a pale tawny olive, lighter than the head, but variably darkened on the margins; inner surfaces a pale buff; antitragoid tuft not conspicuous. *Fore* and *hind limbs* like the sides externally, but less grizzled; internally, like the ventrum. *Manus* and *pes* much paler than in the forms of *B. lesueuri* and in *B.p. ogilbyi*; a uniform greyish white, very faintly tinged with buff. *Tail* with the dorsal hairing proximally

more erect than in the species named; colour distribution much as in the latter but with the proximal russet areas dulled to buffy drab, gradually darkening to blackish brown over the crest which may occupy  $\frac{1}{2}$  of the length of the tail and reach 25 mm.; in two specimens the terminal 12 mm. is pure white; the crest is less defined than *B.p. ogilbyi* and its darkest parts are still grizzled with white; the lateral surface is buff fading to buffy white on the ventral surface.

Three of the skins examined were taken in mid-winter and the other in mid-summer, but though they show slight differences in general warmth of colour, degree of grizzling and density, these are not obviously related to a seasonal or sexual factor.

In comparison with *B. lesueuri* and *B.p. ogilbyi* the pelage of *B. cuniculus* is generally conspicuous for pallor; its lighter examples are decidedly paler, colder in tone and more conspicuously grizzled than either of these. Its darker variants approach them in colour, but have the further distinction of a much longer pelage, a ruff on the nape, and near white hands and feet. The diagnostic value of the hip stripe is doubtful.

### CRANIAL CHARACTERS

In the 11 skulls examined, 10 are fully adult at the P<sup>4</sup>M<sup>4</sup> dental phase and one is subadult and at the tooth change. The series is more uniform both metrically and non-metrically than any other *Bettongia* group recently examined (1958), the mean variation in 20 linear dimensions being 9 per cent.

The skull is the largest of the genus, the range of its chief dimensions overlapping the maxima for *B.p. ogilbyi* and *B. lesueuri* or showing a plus clearance; with an average deviation of the mean values of  $\pm 7$  per cent. from those of the former. The mean displacement volume is 66 cc. as against 64 cc. for *B.p. ogilbyi* and a range of 53-64 cc. in three populations of *B. lesueuri* recently studied. The ossification is light—the mean adult weight of the prepared skull being 16 g. as in the smaller *penicillata*; its surfaces smooth and with muscular ridging even more reduced.

In general outline (Pl. 1, Fig. A-E) the skull is close to *B.p. ogilbyi* with which comparison is chiefly made hereunder. The breadth/length ratio is .54-.57 (.55); the rostral index is .41-.43 (.42), and the facial index 223-241 (232).

The rostrum is conical and steeply tapering, but shallower. The proportions of the nasal bones are much the same, but the expanded portion is more extensive and its posterior margins bowed backwards and gently rounded at the corners, and commonly just reach or slightly exceed the interorbital line. The zygomatic arches slightly wider anteriorly, their maxima at or anterior to the midpoint. Interorbital space relatively still wider, remaining quite parallel sided in the oldest skulls available, its concavity rather greater and its edges smooth and rounded. Temporal crests very weakly developed; the interparietal persistent and constant, sharply triangular not semilunar nor crescentic.

In lateral aspect the premaxillae usually make a smaller contribution to the wall of the orbit than in *B.p. ogilbyi*, but with wide variation in the extent of the premaxillary and maxillary suture with the nasals. The orbital plate of the lachrymal is very large and the maxillary process below it, correspondingly reduced, sometimes to a mere splint and in three cases to extinction. In these latter skulls the lachrymal articulates directly with the palatine as in *Potorous* and *Onychogale* and many polyprotodonts. This feature is a good distinction of *B. cuniculus* from *B. lesueuri* and *B. penicillata*, in which as in most *Macropodidae* the orbital process of the maxilla is a substantial squarish element frequently more than half the area of the lachrymal and sealing off the latter from

contact with the palatine. The zygomata are weak and shallow as in *B.p. ogilbyi*. The supratympanic canal is not completed by bone, though the process of the squamosal which is chiefly responsible for the closure in *B. tesuerti* is strongly developed. The squamosal frontal contact on the temporal wall is constant.

The structures of the palate are generally similar, such proportional differences as occur being caused chiefly by the different character of the secutor  $P^1$  and the greater parallelism of the molar rows. The anterior palatal foramina are both absolutely and relatively larger, and the breadth of palate at  $M^2$  also — the latter averaging 20 per cent. of the basal length. The diastema and the posterior vacuities are relatively shorter, the latter reaching to about the middle of the anterior lobe of  $M^2$ ; they are equally broad and are almost entirely invested by the palatine, a small portion of the anterior margin only, sometimes formed by the maxillae; paired satellite vacuities are sometimes developed in the maxillae. The bulla is much smaller, its length averaging about 10 per cent. and its breadth 26 per cent. less than in the smaller *B. penicillata* skull and its volume is probably less than one-half; as in that species, however, when aged, a thin lamella descending from the ectopterygoid margin of the alisphenoid may reach the anterointernal wall of the bulla, roofing over the foramen ovale and its attendant groove to form a closed canal.

The occipital plane is much as in *B. penicillata*, the paraoccipitals and the mastoid process also, but rather stouter and the latter are not always closely contoured to the bulla.

Mandible, comparatively slight, the maximum breadth, breadth of ascending process and depth of ramus below  $M_2$  and breadth of condyle all relatively lower; masseteric fossa and foramen with a similar range of development, but the process of the angle is shorter and more obtuse.

### DIMENSIONS

The following figures give the range and approximate mean of the dimensions in a bisexual series of 9 skulls of adults at the  $P^1M^1$  stage: Greatest length, 79.7-84.1 (82.2); basal length, 68.6-72.9 (71.2); zygomatic breadth, 44.0-46.6 (45.4); nasals length, 33.6-36.8 (34.8); nasals greatest breadth, 13.6-16.0 (14.3); nasals least breadth, 7.0-8.3 (7.8); rostrum depth, 15.0-16.0 (15.3); interorbital constriction, 19.0-21.0 (19.6); palate length, 45.6-48.0 (46.7); palate breadth inside  $M^2$ , 14.0-15.2 (14.5); anterior palatal foramina, 3.4-4.9 (4.3); diastema, 12.5-14.2 (13.4); bulla length, 12.9-13.4 (13.1); bulla breadth, 6.7-8.0 (7.3); basicranial axis, 20.8-22.2 (21.4); basifacial axis, 48.4-51.7 (50.4); facial index, 223-241 (232); mandible maximum breadth, 39.1-41.4 (40.4); depth of ramus below  $M_2$ , 8.5-9.6 (9.0); breadth of ascending process, 12.4-13.4 (12.9).

### SKELETAL CHARACTERS

The following data is derived from the complete prepared skeleton of the young adult male, the flesh measurements of which are given above: Vertebrae; cervicals, 7; thoracic, 13; lumbar, 7; sacral, 2; caudal, 22. Scapula length, 44; do. maximum breadth, 21; clavicle length, 25.5; humerus length, 39; do. distal breadth, 13.7; radius length, 45.5; do. maximum breadth, 5.5; ulna length, 55.5; do. maximum breadth (coronoid), 8.0; femur length, 93.7; do. proximal (trochanteric) breadth, 19.5; do. distal (condylar) breadth, 18.0; tibia length, 115; do. proximal breadth (medial aspect), 19.5; fibula length, 112; do. greatest breadth (proximal), 7.9; pelvis maximum length, 88; do. iliac breadth, 51.0; do.

acetabular breadth, 52.6; do. ischial breadth, 50.5; epipubic maximum length, 12.5; do. articular breadth, 7.7.

### DENTITION

The semblances of the dentition (Pl. 1, Fig. F-I) are divided, the incisors favouring *B. penicillata*, the premolars *B. lesueuri* with some degree of intermediacy, and the molars combining the crown features of the former, with metrical characters quite different from both; the mean variation in linear dimensions of post-diasternal teeth is 12 per cent.

The incisor rows meet at a somewhat wider angle than in *B. penicillata*.  $I^1$  is a relatively small tooth, its dimensions about as in *B.p. ogilbyi* and decidedly smaller than in *B. lesueuri*. Tate (1918) implies that this tooth is longer in *cuniculus*, though he does not quote dimensions for it, but I cannot substantiate this in the present material. It is comparatively upright and the medial surfaces are separated by a wider interval than usual, and in anterior aspect have an outward (lateral) curvature culminating in eversion of the tips (Pl. 1, Fig. F); dorso-ventral height 4.7-6.6 (5.8); antero-posterior breadth, 2.5-3.6 (3.0).  $I^2$  is larger than in *penicillata* but has much the same proportions; it is much narrower transversely and less rugged than in *lesueuri*. The height of its crown is much reduced in aged skulls, a condition which may exaggerate the apparent height of  $I^1$ ; antero-posterior length, 3.0-3.2 (3.0); transverse breadth, 1.8-2.0 (1.9).

$I^3$ , as represented by the series means, is somewhat shorter dorso-ventrally and longer antero-posteriorly than in either of the above species, but changes in shape of this tooth are so rapid that without more age phases than are available, it is difficult to decide whether this is characteristic of the species or simply of the phase measured. Its general resemblance to that of *B.p. ogilbyi* is close, and in particular there is no inturning of the crest as in *B. lesueuri* and *Aepyprymnus*; dorso-ventral height, 2.5-3.6 (3.1); antero-posterior length, 2.5-3.6 (3.0).  $I_1$  is a larger tooth than in *penicillata* but similarly proportioned; narrower than in *B. lesueuri*; antero-posterior length, 12.8-14.0 (13.3) and breadth, 3.2-3.6 (3.3).

The canine is smaller than in *B.p. ogilbyi* and about equal to that in the lower South Australian *B. lesueuri*; its alveolus lies on the maxillo-premaxillary suture which, as Tate has shown, often approaches it obliquely from behind rather than above; dorso-ventral height, 3.3-4.1 (3.8).

Both the 3rd (and more especially) the 4th premolars are much longer teeth than in *B.p. ogilbyi* and in this approximate to the standards of *B. lesueuri*. Their alignment in the tooth rows is normal, the axis in the upper teeth being nearly parallel to the midline of the palate. The profile of the crests is straight or nearly so, though in  $P^1$  when quite unworn, it may show a slight posterior concavity and although the wall is higher anteriorly than posteriorly, the disproportion is much less than in *B. penicillata*. Hysodontism as gauged by the ratio of greatest height (of enamel) to length is intermediate but much nearer to *B. lesueuri*.

$P^2$  narrower and less bulky than in the other species, its maximum breadth posterior to midpoint and with a constriction at about its anterior  $\frac{1}{2}$ , and its outline as seen from above more elongate and less regularly oval; grooves 5.  $P_2$  is very similar, the length as compared with its opponent, reduced by about 6 per cent. and the breadth and height by about 5 per cent.; grooves 5. The dimensions of a single example of  $P^3$  and  $P_3$  are respectively: length, 5.1, 4.3; breadth, 2.5, 2.4; height (of enamel wall), 3.5, 3.3.

$P^4$ , the secator, is also a narrower tooth than in either *B.p. ogilbyi* or *lesueuri*, but is much longer than in the former, its length overlapping that of the



Central Australian population of *B. lesueuri* which it resembles in general rather closely; its postero-internal talon and ledge are equally variable and may be virtually absent, but the maximum development of these features is less, and it differs in the deeper hollowing of the buccal face below the cingulum. Though the tooth as a whole is nearly parallel to the intermaxillary suture, there is some torsion of crest, with very slight extraversion of the anterior portion, which is accentuated by wear. Distinct grooves 6 in 70 per cent., 7 in 30 per cent. of examples, but additional vestiges are sometimes present as in all the species.  $P_4$  is similar in its general characters to the upper tooth; its length is reduced by 11 per cent., but its breadth and height are both slightly increased; the overall size reduction is therefore less than in the other two species; a posterior talon and ledge are not developed. Grooves 6 in 30 per cent., 7 in 70 per cent. of examples; they are shorter than in the other species and have a tendency to bifurcate in their lower course and become lost in obscure crenellations of enamel. Range and approximate mean of dimensions in 10 slightly to moderately worn examples of  $P^1$  and  $P_4$  respectively are: antero-posterior length, 7.5-8.9 (8.2), 7.0-7.6 (7.3); breadth, 2.7-3.1 (2.9), 2.8-3.2 (3.0); height (of enamel), 2.9-4.2 (3.7), 3.6-4.5 (4.0).

The milk premolars are larger than those of *B.p. ogilbyi* and *B. lesueuri* but appreciably narrower.  $MP^1$  is about equal in crown area to  $M^1$  and its trenchant antero-external cusp is very strongly developed; much more so than in these two species and almost as in *Aepyprymnus*.  $MP_4$  much smaller, its crown nearly triangular through reduction of the antero-external cusp. Dimensions of a single example of  $MP^1$  and  $MP_4$  are respectively: antero-posterior length, 3.9, 3.5; breadth anterior lobe, 2.8, 2.4; breadth posterior lobe, 3.3, 2.8.

The upper molar rows are very weakly arched, with the anterior interval but slightly greater than the posterior. The metrical characters of the molars of *B. cuniculus* are markedly distinct from those of *B. penicillata* and *B. lesueuri*; absolute dimensions are higher in most categories, the length of  $M_s$  1-3 *in situ*, exceeding the means of the combined South and Central series of *B. lesueuri* by 10 per cent. and the sum of the crown areas by 20 per cent., while the superiority over *B.p. ogilbyi* is still greater.

In relative size as interpreted by the sectional crown areas, the 2nd is invariably the largest molar both above and below, while in the upper jaw  $M^2$  is sometimes smaller than  $M^3$ , a condition not seen in the other species examined;  $M_1$  is invariably smaller than  $M_3$ . The overall antero-posterior declension in size is also much less than in *B. penicillata* or *B. lesueuri*, the index of reduction being 1.5-2.1 (1.8) in the upper and 1.3-1.7 (1.4) in the lower teeth. The molar formulae and their approximate frequencies in the upper jaw are  $M^2 > M^1 > M^3 > M^4$ , 70 per cent., and  $M^2 > M^3 > M^1 > M^4$ , 30 per cent.; and in the lower jaw,  $M_2 > M_3 > M_1 > M_4$ , 100 per cent.; the range and approximate mean of the crown areas expressed as percentages of those of the first molars are  $M^1$  (100);  $M^2$  104-123 (111);  $M^3$  90-107 (97);  $M^4$  52-72 (62); and  $M_1$  (100),  $M_2$  117-134 (125);  $M_3$  107-125 (114);  $M_4$  81-96 (88).

In the size relations of upper and lower molars a notable feature is that  $M^3$  as well as  $M^1$  and  $M^2$  is invariably larger than its lower opponent,  $M_1$  alone of the lower series exceeding the upper tooth with a frequency of 86 per cent. Shape differences are also appreciable; there is a general tendency towards narrowing of the molars and breadth > length occurs as a minority frequency in two molars only ( $M^1$ ,  $M^2$ ), whereas in *B.p. ogilbyi* and *B. lesueuri* this condition is represented in all molars, and is dominant in four teeth in the former species and in three of the latter. Further, the condition, posterior lobe > anterior



lobe, which is dominant in both  $M^1$  and  $M_1$  of the above species, is lost in  $M^1$  of *B. cuniculus*, but persists in  $M_1$  with a frequency of 100 per cent.

The range and approximate mean of the antero-posterior length, breadth of anterior lobe and breadth of posterior lobe, in the molars of a bisexual series of 11 skulls, is as follows:  $M^1$ , 4.2-4.9 (4.5); 4.2-4.6 (4.5); 4.0-4.6 (4.2);  $M^2$ , 4.6-5.1 (4.8); 4.5-5.1 (4.7); 4.1-4.6 (4.3);  $M^3$ , 4.3-5.1 (4.7); 4.1-4.7 (4.3); 3.6-4.2 (3.8);  $M^4$ , 3.3-4.0 (3.8); 3.0-3.9 (3.5); 2.7-3.0 (2.9);  $Ms^{1-3}$  (*in situ*) 13.4-14.6 (14.0); and in the mandible:  $M_1$ , 4.0-4.5 (4.3); 3.4-3.8 (3.5); 3.5-4.0 (3.8);  $M_2$ , 4.6-5.0 (4.8); 4.0-4.6 (4.2); 3.7-4.2 (4.0);  $M_3$ , 4.3-4.6 (4.5); 4.1-4.4 (4.3); 3.6-4.1 (3.8);  $M_4$ , 3.8-4.3 (4.1); 3.6-3.9 (3.8); 3.0-3.3 (3.2);  $Ms_{1-3}$  (*in situ*), 13.1-14.0 (13.5). In examples showing heavy wear on the crowns, interproximal wear between molars is also appreciable, and the value for  $Ms^{1-3}$  may fall to 12.3.

The molars are slightly more brachydont than in *B. penicillata* and decidedly more so than in *B. lesueuri* and the working surface occupies a larger proportion of the crown than in either. The crown pattern is relatively undeveloped as in the former, the cusps and lophs being generally low and obtuse, with the longitudinal elements reduced much below the *B. lesueuri* condition; the midlinks well developed in that species and feebly in *B. penicillata*, are absent. The posterior lophs on the upper 2nd and 3rd molars are scarcely developed as continuous transverse ridges, the buccal and lingual cusps being almost completely separated down to base level by a longitudinal median fissure. The anterior lophs of these teeth, and both anterior and posterior lophs of the lower molars nevertheless, although lower, are often more continuous and more extended transversely than in either *B.p. ogilbyi* and *B. lesueuri*.

Accessory cuspules corresponding to those of *B.p. ogilbyi* are very weakly developed on the 1st and 2nd upper molars in two skulls only. In one skull,  $M^1$  in one maxilla is much smaller and simpler than in the other; in all others the posterior molars are structurally and functionally normal bilobed teeth, appearing regularly in the succession. There are no examples of supernumerary molars or incisors.

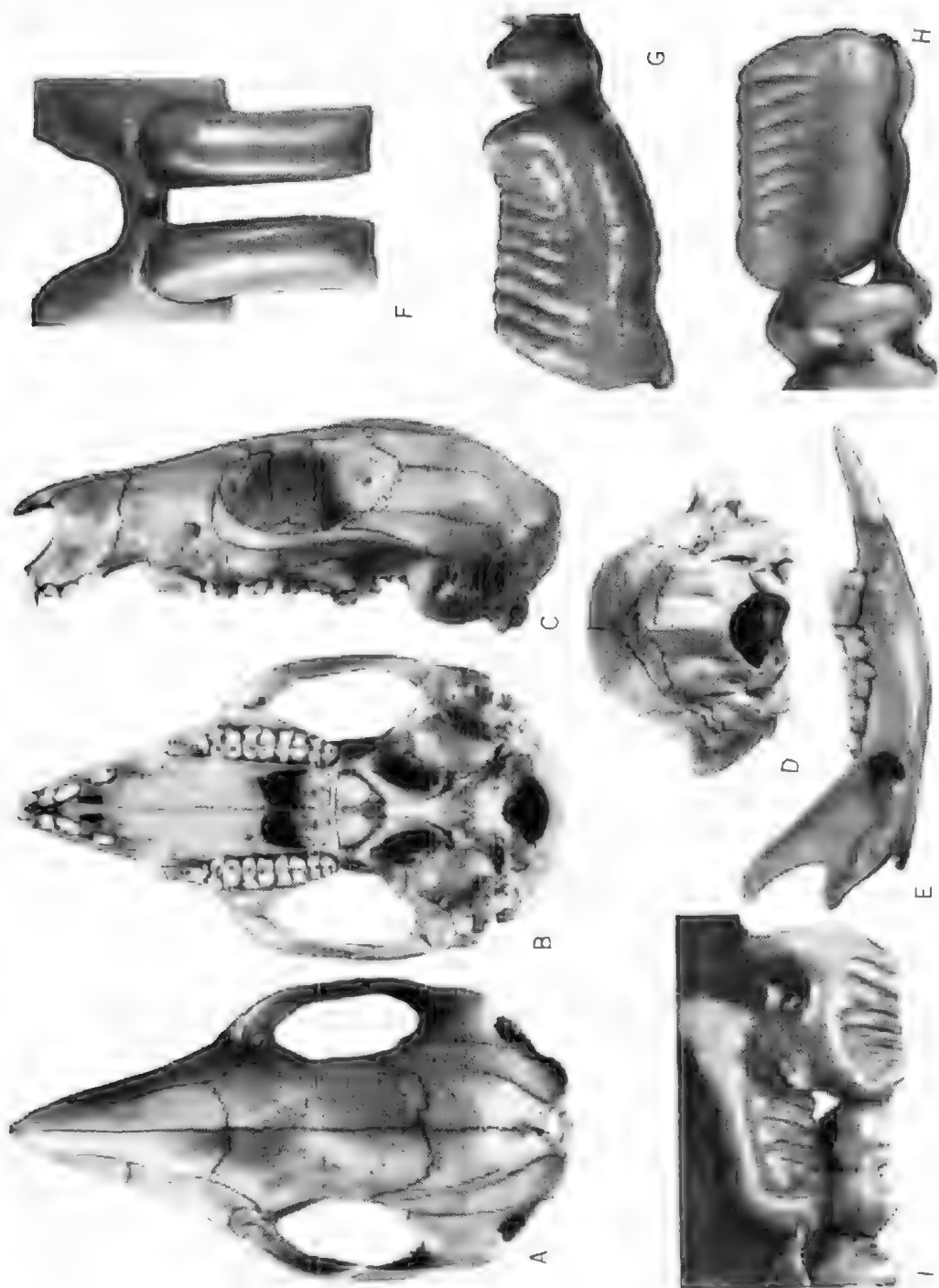
In the single example of the tooth change afforded by the series,  $P^1$  is erupting simultaneously with  $M^4$ .

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## EXPLANATION OF PLATE I

- Fig. A. Dorsal aspect of the skull of an adult ♂ from the upper Macquarie River, eastern Tasmania. (x 0.9.)  
 Fig. B. Palatal aspect of the same. (x 0.9.)  
 Fig. C. Lateral aspect of the same. (x 0.9.) The pterygoid plate is not shown.  
 Fig. D. Occipital aspect of the same. (x 0.9.)  
 Fig. E. Lateral aspect of right mandibular ramus of the same. (x 1.0.)  
 Fig. F. Anterior aspect of upper 1st incisors of the same. (x 4.4.)  
 Fig. G. Buccal aspect of an unworn  $P^4$  of the right side in another young adult. Same locality. (x 4.7.)  
 Fig. H. Buccal aspect of slightly worn  $P_1$  of the right side in another young adult. Same locality. (x 4.3.)  
 Fig. I. The right maxillary tooth change in an advanced subadult from the same locality.  $P^4$  (upper) is simultaneously displacing  $P^3$  (lower right) and  $MP^4$  (lower middle);  $M^1$  (lower left) persisting *in situ*, is represented by its anterior lobe. (x 4.7.)



# SUBFOSSIL POTOROINAE (MARSUPIALIA) FROM SOUTH AUSTRALIA

BY H. H. FINLAYSON

## Summary

Collections of cranial and dental material of subfossil Potoroinae from South Australia are reviewed and compared with recent populations. In *B. lesueuri* Q and G. the wide range of variation in skull characters and the sporadic dwarfism found in recent populations are confirmed in a cave series of smaller average size from Yorke Peninsula. A small form of *B. penicillata* Gray, close to *B.p. ogilbyi* Gould but with smaller 4th premolars, is noted as persisting in the Devon Downs archaeological site in the lower Murray Valley from about 5000 B.P. almost to the present. A phase of *B. cuniculus* Ogilby, at present an exclusively Tasmanian species, is recorded from volcanic ash beds at Tantanoola. *Potorous morgani* Finlayson closely allied to *P. platyops* Gould of Western Australia and originally described from Kangaroo Island is now recorded for the mainland of South Australia in the middle and upper levels of Devon Downs.

## SUBFOSSIL POTOROINAE (MARSUPIALIA) FROM SOUTH AUSTRALIA

by H. H. FINLAYSON

[Read 9 October 1958]

### SUMMARY

Collections of cranial and dental material of subfossil Potoroinae from South Australia are reviewed and compared with recent populations.

In *B. lesueuri* Q and G. the wide range of variation in skull characters and the sporadic dwarfism found in recent populations are confirmed in a cave series of smaller average size from Yorke Peninsula.

A small form of *B. penicillata* Gray, close to *B.p. ogilbyi* Gould but with smaller 4th premolars, is noted as persisting in the Devon Downs archaeological site in the lower Murray Valley from about 5000 B.P. almost to the present.

A phase of *B. cuniculus* Ogilby, at present an exclusively Tasmanian species, is recorded from volcanic ash beds at Tantanoola.

*Potorous murgoni* Finlayson closely allied to *P. platyops* Gould of Western Australia and originally described from Kangaroo Island is now recorded for the mainland of South Australia in the middle and upper levels of Devon Downs.

During a review (1958) of recent members of this sub-family, chiefly from South and Central Australia, the characters and status of its representatives in some osteological material from aboriginal archaeological sites and cave deposits, have come up for consideration. The collections studied are for the most part in the South Australian Museum and have been culled from 13 sites extending from the North Flinders Ranges to Kangaroo Island and the lower South-Eastern district, the chief collectors being Mr. N. B. Tindale and Mr. H. M. Cooper of the Anthropological Department of the Museum and the Cave Exploration Group of South Australia. Brief references by the writer in the form of provisional identifications have already appeared in contributions by the above authors. For the most part, the age of the deposits yielding the material is only vaguely known from field observations on the site; but in the case of the Devon Downs collections, dates for several horizons based upon C14 determinations have been published by Tindale (1957) and the earliest of these, relevant here, is about 5000 B.P. Much of the collection, however, is much more recent and some of it may be no more than a century or so old.

Four species are represented, referable to described forms but providing a useful extension of knowledge on the variation in cranial and dental characters which must be expected within their limits.

### BETTONCIA LESUEURI Q & G.

The cranial material under this head falls into two main groups; a miscellaneous assemblage of specimens consisting mostly of mandibular fragments derived from widely scattered sites — and a series of relatively complete skulls from caves in the Curramulka district of Yorke Peninsula. The latter provides the greater interest and will be dealt with first.

Material from these caves was first obtained about 30 years ago and has since been augmented at intervals, most recently by the Caves Exploration Group, so that 25 skulls from the very restricted area of the site are now available. The bone is heavily impregnated with deliquescent calcium and magnesium salts, but is otherwise unmineralized and well preserved; about  $\frac{1}{2}$  of the

skulls are stained a deep chocolate colour, but the remainder are almost as clean as a recently macerated preparation, and with one possible exception, are entirely free from soft tissue and fat. The series is well balanced between adults at the P<sup>3</sup>M<sup>2</sup> phase, and sub-adults from P<sup>3</sup>M<sup>2</sup> onwards and in these respects gives more information on age changes than could be safely inferred from the recent series from lower South Australia and Central Australia just studied (*supra*). Eleven separate mandibular rami were also taken and some of these were associated by the collectors with individual skulls; but as dental unconformities asperse the validity of this in some cases, I have disregarded it in all and studied the mandibles separately as a nondependent group. Other genera of mammals associated with *Bettongia* in the deposit are all of recent facies and include *Lagorchestes*, *Thylogale*, *Trichosurus*, *Thalacomys* and *Canis*.

### CRANIAL CHARACTERS

*Metrical.* The largest adult skulls are decidedly smaller than the largest in the recent series from lower South Australia and about equal to the largest from Central Australia. However, the size range though considerable is less than in the other groups, and its smallest skulls are bigger than in these and there are numerous intermediate conditions, which are indistinguishable in this regard in all three. In detailed linear dimensions the average range is smaller than in the lower South Australian group in the proportion of 14 to 22 and in most items can be completely merged. The approximate means, however, in 17 of 23 dimensions examined are lower by from 2.11 per cent. with a mean difference of 6 per cent.

Outstanding differences in the approximate means of absolute dimensions are: depth of rostrum which is less than in either; length of anterior palatal foramina which is equal to the recent South Australian figure and 15 per cent. higher than for Central Australia; large size of bulla in which length is equal to the recent South Australian mean and the breadth 4 per cent. greater; while both are 6.7 per cent. greater than in Central Australia; and a slight mandible in which breadth of ascending process and condyle are again lower than in either.

On eliminating the size factor by expressing absolute dimensions as percentages of basal length a comparison of mean proportional development between the three groups is possible. This indicates that the chief average distinctions of the lower South Australian skull from that of Central Australia are maintained by the Curramulka series in the lower zygomatic breadth, shallower rostrum, lower facial index, shorter mandibular body and narrower condyle and ascending process, while the distinction of the longer anterior palatal foramina is accentuated, these being both absolutely and relatively longer than in either. On the other hand, intermediate conditions occur and in a few items the agreement is with the Central Australian group, as for example in the falling off of relative depth of mandibular ramus and in the increased relative length and breadth of bulla — the last is particularly notable.

The overall metrical balance arrived at by this tysonian method favours the Central Australian condition in absolute dimensions and the lower South Australian in dimensions relative to basal length; but there are wide overlaps in many items and no clearance in the range of any.

#### *Non-metrical Morphology*

Features such as the taper of the rostrum and interorbital space, shape of the nasal bones, shape of the zygomatic arch, curvature of interparietal, extent and position of temporal crests and axial inclination of bulla are as variable

here within strictly limited age groups (as interpreted by dentition) as in the recent South and Central Australian series, and serve to connect all three by numerous links. The skull is generally smoothly rounded and with slight muscular impressions and less dense in substance and less rugged than in Central Australia. The general resemblance in non-metrical characters is possibly more often with the South Australian series; but some of the largest and broadest skulls are a close match for Central Australian types.

The foramen ovale is partially canalized in three examples but to a lesser extent than occurs in *B. ciniculus*. The orbital process of the maxilla is invariably present and the lachrymal is never in contact with the palatine. The fronto-squamosal contact at the temporal pterion is constant; but in two examples is exceedingly narrow, 2 mm. or less, and more irregular than I have yet seen it in this species.

#### *The Subadult Skull*

A difficulty in interpreting cranial variation in series of *Bettongia* arises in the comparatively slight differences which distinguish the adult from the subadult skull, both in relative proportions and in non-metrical features. This is true of all Potoroinae in greater or less degree; but is particularly so with short muzzled forms such as the present species, in which differential factors in regional growth rate of the skull are much less responsive to age changes than in the Macropodinae. The Curramulka series consists of nearly equal numbers of adults ( $P^1M^1$ ) and subadults of the dental categories  $P^3M^2$ ,  $P^3M^3$ , and  $P^3M^4$ , and the opportunity has been taken therefore of making comparisons between them under more favourable conditions than obtained with other series examined.

Taking the subadults *en bloc*, it would appear that neither the facial index, rostral index (length of muzzle/greatest length), nor breadth index (zygomatic breadth/greatest length) afford any appreciable distinction between these groups. In long muzzled forms, such as *B. penicillata*, the testimony of the rostral index and facial index is often quite contradictory; the former increasing with age, while the latter may do so or not; in *B. lesueuri* neither appears to respond reliably. In relative dimensions as shown by the percentage basal length relation, 15 items of the 21 examined show substantial agreement (less than 3 per cent. difference), while of the remainder the length of nasals, least breadth of nasals, and breadth of palate average 6-7 per cent. lower in subadults and the breadth of condyle, ant. palatal foramina and interorbital breadth 4-7 per cent. higher. The most consistent difference is in the relative dimensions of nasals and interorbital breadth, but here as in all not a few examples fail to conform, and a conclusion tentatively reached in earlier tests is therefore confirmed—namely, that within these dental limits a characteristic subadult skull form, if it can be said to exist at all, is largely swamped by individual variation and its metrical definition rendered impracticable.

The position is similar in non-metrical characters, and practically all shape variants both of the entire skull and of its constituent bones occur irrespective of age. A zygomatic outline, which tapers anteriorly, somewhat as in *Trichosurus*, is more frequent in subadults but by no means confined to them. Closure of the basioccipito-sphenoid suture appears to take place generally between the dental stages  $P^3M^3$  and  $P^4M^3$  but it is not reliable as an indicator of adult status; closed sutures have been observed in skulls with unworn  $P^3M^2$  and open in skulls with worn  $P^4M^4$ . With experience it is possible to sort skulls into approximate age groups without reference to dentition, by employing subjective qualitative tests not easy to define in few words, but the  $P^4M^4$  coincidence is by far the best criterion and is not, in my present belief, liable to serious error.

*Dwarfed Skulls*

The Curramulka material provides further evidence of the characteristic condition of sporadic dwarfism, which has already been noted in recent series of *B. lesueuri* both from Central and lower South Australia and in *B. penicillata ogilbyi* (op. cit.). The size reduction of the smallest examples as compared with the rest of the series is less extreme in the present case than in either of the recent series, but they occur with greater frequency. This has provided an opportunity of testing and confirming the tentative conclusions which were based upon the single examples which were found in the other geographically widely separated groups.

The examples are fully adult skulls at P<sup>4</sup>M<sup>4</sup> and the chief dimensions of the two smallest are set out in tabular form below for comparison with their recent analogues and with a skull of the largest size group of each series.

TABLE 1.

Comparison of some dimensions of a skull from the largest size group with the smallest, in 3 series of *Betlongia lesueuri*.

(All at P<sup>4</sup>M<sup>4</sup>)

	Central Australia Recent.		Lower South Australia Recent		Curramulka Subfossil		
Basal length	60.0	54.4	65.5	54.0	61.0	57.2	57.8
Zygomatic breadth	45.6	40.5	45.7	39.5	44.0	41.7	40.0
Nasals length	26.2	22.8	29.6	23.3	27.9	25.6	26.0
Depth rostrum	13.4	12.7	14.1	11.5	13.0	11.8	11.8
Interorbital breadth	14.1	15.2	16.1	16.6	15.0	13.7	14.9
Palate length	37.5	35.3	39.0	33.3	37.3	35.0	34.8
Ant. palatal foramina	2.7	3.8	3.5	3.2	2.7	3.2	3.7
Diastema	7.3	8.3	7.8	6.7	7.0	8.0	7.5
Bulla length	17.0	15.1	18.3	14.6	17.3	17.3	18.0
Bulla breadth	13.3	11.5	13.8	10.5	14.2	13.7	12.7
Facial index	171	191	170	165	173	174	172
M <sup>1</sup> - <sup>3</sup>	13.0	11.4	14.0	11.3	12.3	12.1	11.7
P <sup>4</sup>	8.7	7.6	8.8	7.7	8.0	8.3	8.3

Examination of these figures and of their percentage relation to the respective basal lengths shows a somewhat higher degree of total differentiation, both in size reduction and detailed proportion in the dwarfs of the recent series than in those from Curramulka. There is very little correspondence in the nature of the proportional change in the three cases; the sign of the change is the same for nasals, anterior palatal foramina and diastema, but the amount varies within wide limits and in other items is quite erratic and unpredictable. In the case of the two Curramulka dwarfs also the divergence occurs in different and unrelated items and is sometimes of opposite sign. These quantitative relations support the qualitative morphology of the skull in denying any special community of structures to the dwarfs, which are obviously as closely related to the rest of the parent series as they are to one another. A notable difference in the two Curramulka dwarfs is the failure of the dentition to keep pace with the cranial reduction, though the difference in this is less when the comparison in these items is extended to the range and mean for the series (*infra*).

Similar dwarfing almost certainly exists in the subadult group, but it is difficult to define; inequality in general size at the same dental phase is frequent in young skulls, but may be due in part at least to differences in growth



rate which would have been later equalized before reaching the adult condition; at the more or less static P<sup>4</sup>M<sup>1</sup> stage such differences may be safely regarded as permanent.

#### Dimensions

The following figures give the range and approximate mean in (1) 13 adult skulls at P<sup>4</sup>M<sup>1</sup> and (2) 12 subadults at P<sup>3</sup>M<sup>2-4</sup>: greatest length, 66.7-71.1 (69.3), 63.8-68.6 (66.3); basal length, 57.2-61.6 (59.8), 55.5-60.0 (57.5); zygomatic breadth, 40.0-44.5 (42.1), 38.8-43.8 (41.7); nasals length, 25.2-28.0 (26.6), 22.8-25.3 (24.1); nasals greatest breadth, 11.2-13.9 (12.5), 11.0-14.0 (12.3); nasals least breadth, 4.6-6.8 (5.8), 4.2-6.2 (5.2); rostrum depth, 11.8-13.2 (12.5), 11.4-12.5 (12.1); interorbital constriction, 13.7-15.5 (14.9), 13.5-15.6 (14.8); palate length, 34.8-37.3 (35.9), 31.0-36.9 (34.4); palate breadth ins. M<sup>2</sup>, 11.0-12.6 (11.7), 9.5-12.1 (10.5); anterior palatal foramina, 2.7-3.7 (3.3), 2.7-4.5 (3.4); diastema, 7.0-10.0 (8.2), 6.6-9.5 (7.8); bulla length, 16.1-18.5 (17.4), 16.0-18.2 (17.0); bulla breadth, 12.5-14.2 (13.2), 11.7-14.2 (12.5); basicranial axis, 21.3-23.7 (22.2), 19.9-22.3 (21.3); basi facial axis, 37.1-41.0 (38.8), 33.8-39.4 (36.6); facial index, 163-190 (174), 168-183 (172); and in 4 adult and 2 subadult mandibular rami: depth below M<sub>2</sub>, 8.0-9.7 (8.9), 8.2-8.8 (8.4); breadth ascending process, 13.1-14.6 (13.8), 12.3-14.0 (13.3).

#### DENTITION

The range in dimensions in the majority of items overlaps the minima for the recent South and Central Australian series and the means are usually below both, though nearer the latter; the mean variation for post diastemal elements is 15 per cent. The dentition as a whole has a tendency to slightness, the reduction in most items being relatively greater than the skull size (basal length) demands and where there are differences in antero-posterior as compared with transverse diameters, the change is almost always in the direction of narrowness, as in the South Australian group.

Prediastral teeth are too few or alveolar damage too frequent to permit of strict comparisons, but I<sup>1</sup>, I<sub>1</sub> and the canine tend to be smaller teeth than in either of the recent series, while I<sup>2</sup> and I<sup>3</sup> are intermediate. The greatest breadth (of enamel) for 9 examples of I<sup>1</sup> is 2.3-2.8 (2.6) and 7 examples of I<sub>1</sub> give a constant value of 3 mm.

P<sup>3</sup> is proportionally reduced in both length and breadth and is close to the recent South Australian condition and narrower than in Central Australia; its grooves vary from 5 to 7—5 occurring in 6 of the samples examined, 6 in 4, and 7 in 2; the 7 grooved variant has not been observed in recent material, but the extra grooves are vestigial and posterior. P<sub>3</sub> has 5 grooves only in the 3 examined. The range and approximate mean of antero-posterior length in 12 examples of P<sup>3</sup> and 3 of P<sub>3</sub> are respectively: 4.7-5.5 (5.1), 4.1-4.5 (4.4); and the maximum transverse breadth of the same 2.5-3.0 (2.6), 2.2-2.7 (2.4). The secutor P<sup>4</sup> has dimensions close to the means for Central Australia and reduced by 5-6 per cent. as compared with those of the recent South Australian material. Its talon development is frequently as marked as in the latter, but is equally variable and the cusp may be almost suppressed; the ratio of posterior breadth to length in the range of wear illustrated is about as in the recent material, but the body of the tooth is frequently slimmer. Grooves vary from 7 to 9, with the maximum frequency with the latter, as is usual; a 10 grooved variant does not occur. Two examples are of interest as showing very slight extraversion of the anterior portion of the crest, reminiscent of the condition in the anomalous form recently referred to tentatively as *B. penicillata anhydra*.

$P_4$  is also a narrower tooth than in the recent series, but its grooves are constantly 8, which is the higher frequency in these also. Anteroposterior length in 13 examples of  $P^1$  and 4 of  $P_4$  (with slight or moderate wear) are respectively 7.2-8.8 (8.1), 6.5-7.0 (6.7) and maximum transverse breadth in the same 2.3-3.2 (2.8) and 2.3-2.5 (2.4).

Of the milk premolars the lower tooth is reduced slightly further when compared with the means of the recent series than the upper one, and the posterior lobe in both is narrower especially in comparison with the Central Australian condition, dimensions in 13 examples of  $MP^4$  and 3 of  $MP_4$  are respectively: anteroposterior length, 3.3-3.8 (3.5), 3.1-3.3 (3.2); breadth anterior lobe, 2.8-3.0 (2.9), 2.0-2.3 (2.1); and breadth posterior lobe 3.0-3.5 (3.2), 2.6-3.0 (2.7).

The molar size as assessed by the approximate crown area (length  $\times$  half sum of the breadth of the two lobes) is smaller in all categories than in either of the recent series; the reduction being particularly marked in  $M^3_4$  and  $M^4_4$  as compared with recent South Australian values. The interrelations of molars in point of size, gauged in the same way, is decidedly nearer the Central than the South Australian condition. The relative enlargement of the 2 posterior teeth characteristic of the latter is not shown. Both  $M^1$  and  $M^2$  are large teeth which increase a collateral superiority of this pair over  $M^3$  and  $M^4$  in the upper jaw, and in the lower, the mean increase of  $M_1$  with respect to  $M^4$  is accentuated still further than in Central Australia. The index of reduction (largest/smallest molar) is 2.4-6.3 (3.6) in the upper jaw and 2.5-3.2 (2.8) in the lower; the mean value for both is higher than in the recent South Australian series and that for the lower jaw is higher than in Central Australia as well. The molar formulae and their approximate frequencies, and the percentage relation of the crown areas of the several teeth to the corresponding first molars is as follows: in the upper jaw  $M^2 > M^1 > M^3 > M^4$  100 per cent. (the conditions  $M^2 > M^3$  and  $M^3 = M^4$  being absent) and  $M^1$  100;  $M^2$  101-115 (108);  $M^3$  54-93 (77);  $M^4$  16-43 (32). In the lower jaw  $M_2 > M_3 > M_1 > M_4$  50 per cent. and  $M_2 > M_1 > M_3 > M_4$  50 per cent. ( $M^3 = M^4$  being absent) and  $M_1$  100;  $M_2$  109-131 (124);  $M_3$  88-113 (99);  $M_4$  41-53 (52).

In shape of molars as shown by the relation of antero-posterior length to greatest breadth and anterior to posterior lobe the agreement is with the recent South Australian condition, many of the molars being still narrower than in that series. The maxima for linear dimensions are here not infrequently with the subadult group, and the following figures for antero-posterior length, breadth of anterior lobe and breadth of posterior lobe are derived from 25 crania and 7 mandibles, irrespective of age:  $M^1$  3.7-4.2 (4.0), 3.5-4.2 (3.8), 3.7-4.2 (4.0);  $M^2$  3.9-4.5 (4.2), 3.8-4.4 (4.1), 3.6-4.2 (3.9);  $M^3$  3.1-4.0 (3.6), 3.0-3.9 (3.5), 2.4-3.5 (3.0);  $M^4$  1.6-3.0 (2.4), 1.7-2.8 (2.4), 1.4-2.0 (1.6);  $M_1$  3.6-4.0 (3.8), 3.0-3.4 (3.2), 3.5-3.9 (3.7);  $M_2$  4.1-4.5 (4.4), 3.7-4.0 (3.9), 3.5-4.0 (3.8);  $M_3$  3.6-4.0 (3.9), 3.5-4.0 (3.7), 3.1-3.5 (3.4);  $M_4$  2.4-2.9 (2.6), 2.5-2.7 (2.6), 1.7-2.1 (1.9). The length of the molar rows in situ are:  $M_{1-3}$  10.9-12.4 (11.8);  $M_{41-3}$  11.6-12.3 (11.9).

The Curramulka series is of interest as confirming in a strict homopatric group of examples what may be called the normal heterogeneity of *B. lesueuri* in cranial characters as already seen in the Central and lower South Australian groups, which were drawn from much wider geographic limits. What was true for the earlier dual comparison is equally so in the present tripartite one, differences being manifest in the average characters of groups rather than in individuals, a large proportion of which are indistinguishable, or so dubiously so, as to be beyond the reach of a practical taxonomy.

There is at present no information on the age of the Curramulka cave deposit, and an alternative view of the high variability of the series might be based on the reasonable assumption that the caves have been acting as traps for a very long time during which the *B. lesueuri* population has undergone changes in average character, particularly in size, and that possibly the smallest adult forms represent an earlier population, and the largest, a later one. Nothing in the appearance of the material as a whole suggests such a stratification. The species was known to occur on Yorke Peninsula in the early days of settlement there, but no recent examples are available for direct comparisons. Moreover, the occurrence of similar dwarfs in recent populations of Central and South Australia would still require explanation. This might perhaps be met by invoking the phenomenon of re-emergence, as accepted in the physical anthropology of Europe in explanation of the appearance of archaic types in urban populations, but there is much against this in the present case.

While there may well be considerable differences in the antiquity of different portions of the series, its dwarfs, as pointed out earlier, do not form a recognisable structural type apart from the similarity in overall size. The position adopted elsewhere (op. cit.) in discussing the same problem as it occurs in *B. penicillata ogilbyi* still seems the more probable; namely, that the dwarfing in this species is due to individual physiological anomalies, which either predetermine the subject to a stunted maturity, or at least predispose it to such when the life cycle is run under adverse conditions.

#### MATERIAL FROM MISCELLANEOUS SITES

For reasons developed above in connection with the normal variability of the species little of theoretical interest can safely be inferred from isolated specimens of infra specific distinction and all that can be done is to record the more conspicuous variations which occur, irrespective of their possible significance. Two such claim attention.

In the lower South-East district of the State at Mount Gambier and Tantanoola, in beds which have been regarded as coeval with the last phase of vulcanism there, examples occur with a narrow  $P_4$  upon which the grooves of the external face are reduced to 7, thus adding considerably to the difficulty of distinguishing the species from others which accompany it (*infra*).

A specimen from the Baldina Creek in the Burra district of the mid-north of South Australia is remarkable for its large size. It is a nearly complete skull without mandible of a young adult at  $P^2M^1$  and is the largest example of any series of *B. lesueuri* measured by the writer. Most of its dimensions exceed the maxima for the recent series from lower South Australia and many of them exceed those of the available skulls from south-western Western Australia. The chief maxima are: greatest length 78.5; basal length 67.8; nasals length 30.7; rostrum depth 14.2; interorbital breadth 17.5; anterior palatal foramina 5; diastema 10.5; bulla 18.8  $\times$  15.0; basicranial axis 24.5; basifacial axis 44.4. Dental dimensions are within the recent South Australian range and the molars ( $Ms^1$  3, 13.0) are characteristically narrow. The left zygoma is lacking, but the estimated zygomatic breadth of 44.6 yields a breadth index of .57, which is low for the species. The skull has no claim to age and its place is obviously with the recent series; tartar crusts are still firmly adherent to the molars, and the circumstances of the find (6 feet deep in loam) which were responsible for its relegation to the subfossil collection are not significant of age in an animal which lives (and dies) in deep burrows of its own making.

**BETTONGIA CUNICULUS** Ogilby

In identifying collections of mandibular fragments of *Bettongia* from the lower South-East district of the State, the inherent difficulties due to normal overlap in dimensions are much increased by the occurrence of a 3rd species, somewhat intermediate between *B. lesueuri* and *B. penicillata*. In examples with worn dentition the difficulties of discriminating between this and *B. lesueuri* may be almost insuperable if the molar sets are incomplete, owing to the occurrence of a 7-grooved and somewhat reduced variant of  $P_1$  in the latter (*supra*). By a fortunate chance the position was clarified by the recovery of an unworn  $P_1$  from the crypt of a mandible, which proved that the intermediate form was a somewhat microdont phase of *B. cuniculus* and the evidence of the premolar was then found to be supported by the molar condition, in which the gradation of the series is slight,  $Ms_{1-3}$  being subequal and  $M_4$  remarkably large — in one case unprecedentedly so, in a mainland species.

The dimensions of  $P_1$  in two examples from volcanic ash beds of Tambora are: length 6.4-6.7; breadth 2.6-2.7; H/L .51-.54; grooves 7;  $Ms_{1-3}$  12.3-12.8;  $M_4$  crown area, 10.2-11.1.

*B. cuniculus* as an extant species is exclusively Tasmanian; it has been claimed as a recent species for Victoria, but as far as I am aware no evidence of its former presence in South Australia has been previously adduced.

**BETTONGIA PENICILLATA** Gray

(1) From southern districts (Kongarati, Mypolonga, Moama, etc.) come a series of specimens broadly referable to the modern form *B. penicillata ogilbyi* recently extinct in South Australia. The range of dimensions determined upon them is wider in most items than in the recent series (*op. cit.*), frequently overlapping both maxima and minima, but the means are generally equal or slightly lower. The group is not only reconcilable with *B.p. ogilbyi* as recently defined, but in some structural details may be said to represent that form *in excelsis*. The premolar  $P_1$  in particular while equal to the modern tooth in size has several of its characteristic features accentuated. The grooves on the external wall are sometimes increased from 7 to 8 and are frequently so on the internal wall and they are deeply incised and conspicuous and continue so almost to the lower margin of the enamel. Extraversion of the axis is marked, the crest making an angle of 15° or more with the lingual margin of  $M_1$  and the height of the blade (enamel) reaches a maximum of 4.6 mm. in unworn teeth, yielding the very high H/L ratio of .70.

The molar rows reach a maximum of 12.8 for  $Ms_{1-3}$  with a mean of 11.6;  $M_4$  is extremely variable, its crown area ranging from 5.2-10.2 (8.1), this maximum exceeding that of modern *B.p. ogilbyi* as represented here. The size sequence is generally  $M_2 > M_1 > M_3 > M_4$  as in the recent series; but there are examples of  $M_2 > M_3 > M_1 > M_4$  and these when they incorporate a large  $M_4$  present a molar combination scarcely distinguishable from that of *B. cuniculus* of Tambora.

A remarkable feature in this group, foreshadowed in a milder form in the recent series, is the anomalous distribution of tooth wear as between molars and premolars in some examples. Mandibles occur in which the molar series is so worn as to be almost denuded of crown detail, even on  $M_4$ , while  $P_1$  is intact in every detail and dimension. Normally, the crowns of molars teamed with an unworn premolar are themselves scarcely touched by wear, while on the other hand a premolar working with molars as worn as these subfossils would be denuded of grooves and reduced to one-half of its nascent height. A relatively late tooth change was inferred (from indirect evidence) for the recent

series (1958) and these present anomalies may be due simply to cases of extreme retardation in eruption of  $P_4$ . On the other hand, they may possibly indicate a revolution in the feeding habits of some individuals, either abnormally envired or abnormally selective of foodstuffs.

(2) A collection from the archaeological site of Devon Downs in the lower Murray Valley is of interest as being derived from a series of stratified beds, systematically excavated by Hale and Tindale (1930) and in part dated by C14 determinations (1957).

The material consists of about 50 fragments of maxillae and mandibles with teeth both *in situ* and displaced, the mandibles being about 1 times as numerous as the maxillae. *Bettongia* is represented in levels 1, 3, 4, 6, 7, 8, 9 and 11, giving a time span of approximately 5000 years, but 3/4 of the material was taken from levels 6 and 7. A selection of 33 of the best preserved examples representing all the levels named has been measured and examined in detail, but in forming conclusions as to identity, reliance has been chiefly placed upon specimens with premolars, as these are diagnostic to a much greater degree than molars. All premolars examined are undoubtedly of *B. penicillata s. lato* and as all molar sets not associated with premolars show about the same variety as those which are, there is a strong probability that this is the only species of *Bettongia* present.

The dental and mandibular characters indicate a small phase of the species roughly intermediate in size between the modern *B.p. ogilbyi* and the small skull described as a dwarf of that form (1958 op. cit. 287) and larger than the types of *B.p. francisca* and *B.p. anhydra*. The series is comparatively uniform and although most items measured give dimensions which overlap the minima of the range for *B.p. ogilbyi*, the means are decidedly lower and after a serial comparison of all specimens it is considered unlikely that that form is represented anywhere in the collection, nor is there evidence of any progressive change from a larger to a smaller type or vice versa with changing age of the beds.

The permanent premolars of both jaws in essential structural points, such as extrusion, torsion and shape, and distribution of grooves are very much as in *B.p. ogilbyi*, but they are narrower teeth, less high anteriorly and the grooves in 50 per cent. of examples are reduced from 7 to 6 and on  $P_2$  from 5 to 4. The molars are also smaller; but although the size sequences are as in *B.p. ogilbyi*, the size gradation of  $M^3$  and  $M^4$  with respect to the subequal  $M^1$  and  $M^2$  is frequently much steeper, approaching the standard of *B.p. francisca* and *anhydra*; a well-marked example of this trend gives the relative crown areas:  $M^1$ 100;  $M^2$ 98;  $M^3$ 63,  $M^4$ 20, with a reduction ratio of 5.0, which is unequalled in *B.p. ogilbyi*. Some dimensions of teeth with the numbers of each measured are as follows:  $P^1$ (4) length, 6.1-7.1 (6.4); do. breadth, 2.5-2.8 (2.6); do. H/L, .56-.64 (.60).  $P_4$ (8) length, 5.8-6.3 (6.0); do. breadth, 2.1-2.7 (2.4); do. H/L, .58-.65 (.62);  $P_3$ (5) length, 3.6-4.0 (3.9); do. breadth, 2.1-2.5 (2.3);  $MP_1$ (7) length, 2.7-3.0 (2.9); do. breadth posterior lobe, 2.3-2.7 (2.5);  $Ms^{1-3}$ (7) 10.0-11.8 (11.3);  $Ms_{1-3}$ (9) 10.5-11.7 (11.2); the minima for the molar rows are derived from very worn examples.

This population evidently persisted almost into modern times and was cœval with that of *B.p. ogilbyi*, but not sympatric with it, so far as the Devon Downs site is concerned. Its existence raises some curious problems regarding its possible relations to the hypothetical subarid race represented by the solitary infantile specimen of the *Waldana karpiteli* and of which it may actually project a former south-eastern extension.

## POTOROUS MORGANI Finlayson

Since this was described from caves at the western end of Kangaroo Island (1938), Mr. H. M. Cooper has taken it in camp site debris at Pennington Bay at the other extremity of the south coast of the island. The specimen was a much-eroded fragment of a mandible, but yielded a perfect crown of  $P_4$  from its crypt. It proves to be a prominently 2-grooved and 3-cusped tooth with the median cusp undivided, much smaller and distinctly lower than its fellows; the axis is straight and the body constricted to correspond to the grooves of the crown, so that in the superior view it is distinctly trilobed with the maximum width near the middle; its length and greatest breadth are identical with those of the type, in spite of the difference in wear.

The species also occurs in levels 1, 6 and 7 of the Devon Downs deposits, as mandibular parts, and comparison of these with the Kangaroo Island mandible may be had from the following figures, which give in turn dimensions for the single type mandible and the range in five specimens from Devon Downs: length, dental foramen to masseteric fossa, 15.8, 15.5-16.3 (15.9) (2); depth below  $M_2$ , 5.8, 6.0-6.8 (6.3) (5);  $P_4$  length, 4.1, 4.1-4.2 (4.1 ca) (3);  $P_4$  breadth, 1.7, 1.8-2.0 (1.9) (3);  $Ms_{1-3}$ , 9.5, 9.7-10.3 (10.0) (5). The mainland mandible appears to be slightly heavier than in the type and the molar rows are a little longer, but there is overlapping in some items and with more insular specimens this would no doubt be increased. The premolar agreement is close, both in dimensions and general structure, though they are all too worn for fine detail to be assessed. The molar sequence is  $M_2 > M_3 > \text{or} = M_1 > M_4$  as in the type; the single mainland example of  $M_4$  is a larger tooth than its Kangaroo Island counterpart, but empty alveoli in mainland jaws indicate that it may sometimes be very minute.

Most of the dentitions are heavily worn and in this condition show a characteristic pattern, in which a remnant of the floor of the midvalley persists as a central island of enamel, sharply defined against the dentine by crescentic margins — they are suggestive of the worn crowns of the (?much larger) "*Hypsi-prinnus*" figured by Johnston in 1881 from the Tertiary of One Tree Point, Tasmania.

*Potorous cf. tridactylus* is chiefly represented by collections from cave deposits on the Glenelg River, and will be reviewed elsewhere with the recent population.

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# **THE GEOLOGY OF THE CAMBRIAN SOUTH OF ADELAIDE (SELICK HILL TO YANKALILLA).**

*BY C. ABELE AND B. MCGOWRAN*

## **Summary**

The Lower Cambrian rocks between Sellick Hill and Yankalilla have been divided into five formations. In the continuous Precambrian-Cambrian sequence the base of the Cambrian has been defined by the lowest known occurrence of Hyolithes in the area. The Cambrian sequence is characterized by a much greater carbonate content than the underlying Marinoan. Correlation with the Cambrian elsewhere in the State is only tentative. The Marinoan rocks in the central part of the area are thrust over the Cambrian to the north-west, and the Cambrian is now found as a series of folds lying mainly between the Black Hill Fault and the Willunga Fault.



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C. ABELE AND B. MCGOWRAN\*

[Read 9 October 1958]

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The Marinoan rocks in the central part of the area are thrust over the Cambrian to the north-west, and the Cambrian is now found as a series of folds lying mainly between the Black Hill Fault and the Willunga Fault.

## INTRODUCTION

The discoveries by Howchin (1897) of *Archaeocyatha* in crystalline limestone at Normanville and Sellick Hill, and of "pteropod remains" (*Hyolithes* Eichwald) in "black marble near Normanville" by David (Howchin, 1897), conclusively proved that at least a part of the rocks of the Mt. Lofty Ranges was of Cambrian age. Howchin (1897) drew a rough geological section of the strata at Sellick Hill, dividing the rocks into argillites, limestones and quartzites. He considered the *Archaeocyatha* to occur at two main horizons and that they formed "a true coralline reef in the Cambrian seas". Howchin admitted the possibility that the succession in the Sellick Hill area was to some extent reversed or extensively faulted.

Madigan (1925) published a sketch-map of the geology of the Fleurieu Peninsula, together with geological sections at Sellick Hill, Myponga Beach, Carrickalinga Head and Carrickalinga Creek. He also published a paper on fossils and the indications of organic activities within the Sellick Hill Limestone at Myponga Beach (1926). Mawson (1925) also examined this limestone, and considered that its origin was associated with algal activity. He measured a detailed section within the Cambrian at Sellick Hill.

The idea that the stratigraphic succession was overturned at Sellick Hill was definitely stated in print by Madigan in 1927. Madigan also mentions the possibility of an unconformity between the Cambrian and the Precambrian rocks. Segnit (1939) published a geological map with observations on the Myponga Beach area.

The publication most helpful to the writers was the geological map of the Yankalilla sheet and its accompanying explanation by Campana, Wilson and Whittle of the Geological Survey of South Australia (1954, 1955).

## PHYSIOGRAPHY

The north-western boundary of the area studied is formed by the Willunga Fault scarp, bordering the Willunga Basin, which is filled with Tertiary and Quaternary sediments.

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To the south of the scarp the topography is the result of rejuvenation of the old peneplained plateau of folded Precambrian and Cambrian rocks. Valley-in-valley topography, indicating at least two periods of rejuvenation, is seen in the creek to the south of the new Sellick Hill road.

The drainage system is oriented approximately perpendicular to the shore line, with numerous bends and small branches at right angles to the main direction. Creeks have cut deeply into the hills, forming steep-sided gullies. This fact, combined with the rough coincidence of the general strike of the beds with the direction of the shore line, enables good structural sections to be observed in the creeks.

Since the limestone is the most common rock type, with Cambrian sandstone practically absent, the area consists of rounded hills. Most of the shore line, however, is characterized by steep cliffs. Where the Sellick Hill Limestone outcrops on the coast, wave-cut platforms are common; the *Archaeocyatha* limestone sometimes forms narrow, sandy beaches.

In the southern part of the area a coastal plain, with sand dunes on its western side, separates the sea from the hills. The plain is covered with flat-lying Quaternary and Permian sediments.

## STRATIGRAPHY

### INTRODUCTION

The locality in which most previous work on the succession has been done is Sellick Hill (Howchin, 1897; Mawson, 1925; etc.). Hence the section through the relatively undisturbed Cambrian strata in this locality is considered as the type section for the Cambrian of the Willunga Scarp and the coastal areas to the south-west. The writers divided the Cambrian rocks into five formations. The lowest is referred to as the Wangkonda Formation and may be subdivided in the north into two members; the *Hyolithes* sandstone at the base, and the limestone member. At Carrickalinga Creek the formation is a calcareous sandstone. The Sellick Hill Limestone succeeds this, and is for the most part a characteristically banded limestone. The Fork Tree Limestone includes the dominant *Archaeocyatha* limestone with a thin mottled limestone at the top. In ascending order, the rest of the succession is included in the Heatherdale Shales, with a lower and a thicker upper member, and the alternating sequence of greywackes and shales of the Kanmantoo Group.

TABLE 1.

Campana and Wilson 1955

Abele and McGowran 1958

Greywacke	KANMANTOO	GROUP	Greywacke
upper slates with phosphatic nodules		upper member	HEATHERDALE SHALES
		lower member	
upper <i>Archaeocyathinae</i> limestone		mottled limestone	FORK TREE LIMESTONE
		<i>Archaeocyatha</i> limestone	
mottled limestones and calcareous slates		SELICK HILL LIMESTONE	
lower <i>Archaeocyathinae</i> limestone		limestone member	WANGKONDA FORMATION
		<i>Hyolithes</i> ss.	
MARINOAN		MARINOAN	

Geographical names used in naming the formations have been taken from a well-known topographic feature (Sellick Hill) and from local pastoral properties. The Heatherdale farm extends over part of the area to the north, where good exposures of the shales are found; similarly the Archaeocyatha and mottled limestones are well exposed on the Fork Tree property, situated inland from Carrickalinga Head. "Wangkonda" is the aboriginal name for a salt pan south of Sellick Beach (Mr. N. B. Tindale, personal communication).

Since Campana and Wilson carried out the most detailed geological mapping of the area previous to the writers' work there, a comparison of their stratigraphic units and the ones described in this paper is tabulated in Table 1.

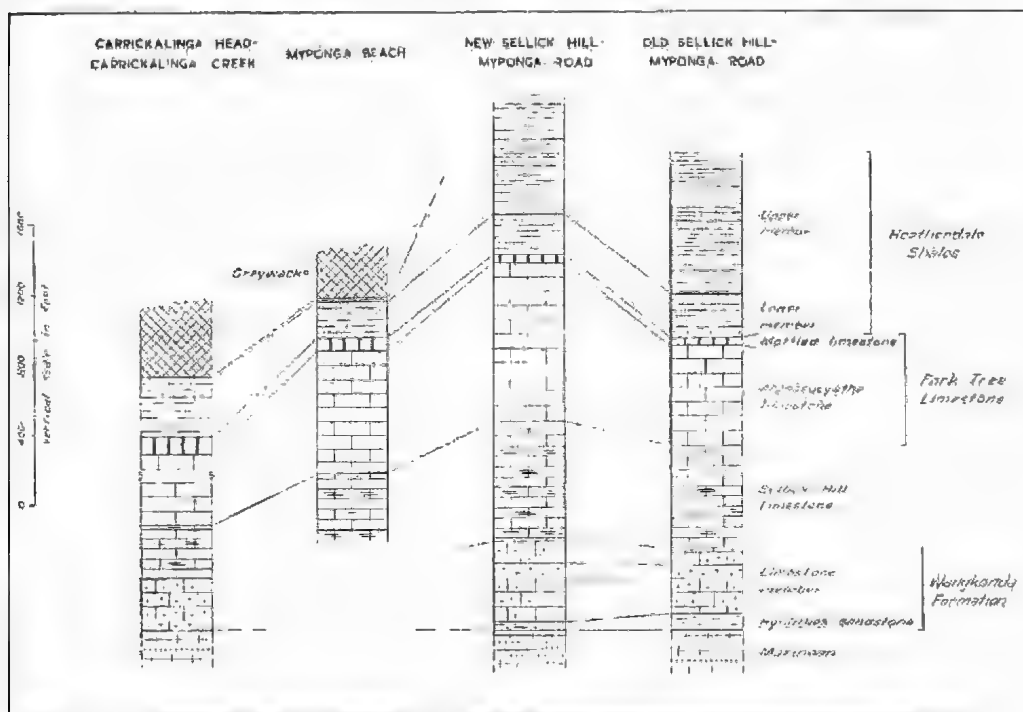


Fig. 1.—Cambrian Sequences, Sellick Hill-Carrickalinga Creek.

A series of stratigraphic sections is given in Fig. 1. The section from the new road includes measurements of the mottled limestone and succeeding units taken where they outcrop on the coast to the south-west. The southernmost section is also composite, and is poorly known due to structural complications. Thus the thicknesses of the Fork Tree Limestone and younger formations can only be indicated very roughly.

## MARINOAN

Although they have not been specifically studied, these rocks of late Precambrian age are mentioned here because of their apparently conformable relationship to the Cambrian strata. They occur in three structurally separated areas: at Sellick Hill in the north and at Carrickalinga Creek in the south the succession is evidently undisturbed; in the central part, from Black Hill to near Carrickalinga Hill, the rocks considered to be of Marinoan age are separated from the Cambrian by the Black Hill Fault.

Below the lowest known fossiliferous unit at Sellick Hill the rocks are mainly shales and slates, sometimes sandy and occasionally slightly calcareous. Exposure is usually fairly good in the creeks, but poor on the hills. Massive quartzites with a tendency to lense occur in the sequence, and felspathic sandstones have been found near the top. The uppermost Precambrian is well exposed on the new Sellick Hill road, where bands of quartzite, interbedded in shales, are better developed than on the old road.

The quartzite bands of Black Hill are evidently equivalent to those on the new road, although the two localities are structurally separated by the fault. The lithology of the sequence beneath these is fairly uniform. Slates are most common, often phyllitic and often calcareous. Small bands and lenses of sandy material may occur in the argillites, and the coarser material is frequently cross-bedded. The sequence contains lensing bands of well sorted quartzite, and also of dense blue limestone. In comparison with the Marinoan at Sellick Hill, a higher carbonate content is evident.

The rocks below the Wangkonda Formation in the neighbourhood of Carrickalinga Creek are highly calcareous. These beds, considered to be of upper Marinoan age, and to be in an undisturbed sequence, include slates, commonly calcareous, limestones, both massive and slaty, and quartzites.

A trend of overall increase in the carbonate content in rocks of this age, from north-east to south-west is evident. However, the trend is in the opposite direction in the Myponga Creek area, and the facies change to the south, toward the highly calcareous Myponga Creek section, is very pronounced.

## CAMBRIAN

### WANGKONDA FORMATION

A peculiar heterogeneous sandstone outcrops above the Marinoan on the new road. It persists to the north-east beyond Sellick Hill and is found below a massive limestone to the south of Black Hill. The rock consists of quartz and felspar grains, mainly angular, and contains dark discontinuous bands and streaks of clay, the whole being set in a carbonate matrix in fresh material. In most outcrops, however, the rock is leached of carbonate. It is slightly more than fifty feet thick on the new road. An important feature is the occurrence of a deeply weathered band of clay containing numerous *Hyalithes*. This band, found on the new road, is only a few inches thick and may be of very limited lateral extent. Although *Hyalithes* has not been found elsewhere in the poorly outcropping unit, the latter is referred to as the *Hyalithes* sandstone because of the importance of this earliest fossil occurrence in the area, and is mapped as the lower member of the formation.

The second member differentiated in the Sellick Hill region corresponds in part to the "lower *Archaeocyathinae*" limestone of Campana, Wilson and Whittle (1954, 1955) and is called the limestone member. It consists of massive, mainly blue-grey and grey recrystallized limestone, with a median band rich in quartz grains. The lower contact of the member is gradational in some places, changing upwards from a thin, discontinuous layer of banded rock to massive limestone. In other localities the contact is well defined.

The member is cut off by the Black Hill Fault to the north of Black Hill. An isolated outcrop occurs to the south of Black Hill, possibly terminated by a fault at one end and covered by Permian at the other. Another isolated outcrop of the member, surrounded by younger formations, occurs slightly more than a mile to the west.

The outcrops of the Wangkonda Formation in the south of the area are separated from those in the north, described above, by a distance of several miles. South of Myponga Creek, the northernmost occurrence of rock outcrops, correlated with the limestone member, is within a loop of outcropping quartzite to the north of the sharp bend in the Myponga Beach-Normanville road. These isolated outcrop patches consist of massive limestone. However, the predominant rock type in the Carrickalinga Creek and neighbouring areas is a calcareous sandstone consisting of abundant quartz grains in a calcareous matrix. It usually weathers to a light buff or greyish colour; fresh surfaces are most commonly dark blue, but less often a light brown, colour. It is essentially a stratified rock, although usually the bedding is poor and parts are quite massive. Less common rock types include pale grey massive limestone and reddish-brown, coarse, arkosic sandstone.

The calcareous sandstone is stratigraphically immediately below the Sellick Hill Limestone and is correlated with the two members of the Wangkonda Formation at Sellick Hill (Fig. 1). Because of the great difference in lithology of the sequence below the Sellick Hill Limestone in the northern and southern part of the area respectively, the correlation of the base of the Wangkonda Formation is not as conclusive as desirable.

The thicknesses of the subdivisions of the limestone member were measured as follows:

On the hill above the new Sellick Hill road:

Upper massive limestone	100 ft.
Median band	85 ft.
Lower massive band	210 ft.

At Sellick Hill:

Upper massive limestone	105 ft.
Median band	75 ft.
Lower massive band	200 ft.

The median band is a markedly lensing unit. The thickness of the Wangkonda Formation in Carrickalinga Creek was estimated by pacing as approximately 300 feet. It increases somewhat inconsistently towards the north.

The writers have failed to find any fossils either in the calcareous sandstone or in the limestone member, though microscopic *Archaeocyatha* were recorded in the latter by Campana, Wilson and Whittle (1955, p. 9). These, however, were stated to average 0.25 mm. in diameter, i.e. much smaller than the earliest known growth stages of this group (Dr. B. Daily, personal communication).

#### SELICK HILL LIMESTONE

This formation, like the *Archaeocyatha* limestone above it, is persistent and easily traced over nearly the whole length of the Cambrian in this area. It characteristically consists of an alternation of bands of pale or dark grey crystalline limestone with buff, shaly bands (Pl. 1, Fig. 4).

There is a wide variation in the thickness, clastic/non-clastic ratio and degree of lateral extension of the bands, and the sharpness of contacts between them. The "shaly" bands are commonly largely calcareous and only relatively more shaly than the "calcareous" bands. Weathering exaggerates the difference in composition. The average thickness of the bands is approximately 2-3 cm.; however, bands as thick as 10 cm. occur. The calcareous and the shaly bands are not always of the same magnitude; sometimes the thicknesses of the shaly bands exceed those of the calcareous bands or vice versa. The shaly layers usually form continuous bands. The calcareous layers are more variable. They are of irregular thickness, showing pinching and swelling, and often disappear

ing entirely for short distances. Commonly the shaly bands are crudely bedded; the limestone layers show such lamination only rarely.

Thin sections were made of part of the rock where the calcareous bands were discontinuous and lumps of limestone were surrounded by more shaly rock. In most sections the shaly laminae drape around the limestone lumps to some extent (this is often observed in the unit at Myponga Beach, where bedding planes, marked by a concentration of small *Hyolithes* (Pl. 1, Fig. 2) exhibit undulations parallel to the irregular upper surface of the limestone bands), or end against the shale-limestone boundary. In only one section the calcareous portions are weakly laminated. The thicknesses enclosed between any two laminae are less in the shaly part than those between the corresponding laminae in the calcareous lumps.

In the Sellick Hill area the formation consists of a lower, mainly clastic part, characterized by an abundance of angular quartz grains (from silt to sand size) in a calcareous matrix. The upper part exhibits better developed banding. The boundary between the two subdivisions is rarely distinctly observable; hence the formation was mapped as a single unit.

At Myponga Beach and neighbouring areas the base of the Sellick Hill Limestone is covered by the sea. The exposed part exhibits well developed banding. Bands rich in coarse quartz grains occur at some horizons, as well as internally brecciated layers.

In outcrops in the Carrickalinga Head region the formation commonly consists of bands of massive, dark blue or purplish-black limestone and finely laminated shale. Weathering produces a characteristic serrated surface—projecting, more or less, consistently thick bands are separated by recessed layers.

Generally speaking, the formation is more shaly towards its base vertically and towards the south horizontally.

The thickness of the formation, as measured at Sellick Hill, is 580 feet. In Carrickalinga Creek it is about 310 feet; in the two creeks to the north it is approximately 400 and 500 feet respectively (calculated from aerial photographs). At Myponga Beach a thickness of over 400 feet is exposed; the rest is covered by the sea.

At Sellick Hill the formation contains *Hyolithes* at various horizons from just above its base to 26 feet above it, as well as worm casts and burrows. At Myponga Beach a remarkably rich concentration of large *Hyolithes* is associated with several layers of internally brecciated rock, each approximately 10 cm. thick, recording minor diastems within the unit. At this same general horizon (approximately 300 feet below the contact with the Archaeocyatha limestone) less notable concentrations of small *Hyolithes* occur at various levels within the shaly bands. This is the best known locality for *Hyolithes*. The gastropod *Helcionella* Grabau and Shimer and brachiopods (Dr. M. F. Glaessner, personal communication; Daily, 1956) also occur here. *Hyolithes* has been found at approximately the same horizon to the east of Myponga Beach. Sponge spicule fragments (*Chancelloria* Walcott) were discovered just below the contact with the Archaeocyatha limestone in the creek about a mile to the south from Myponga Beach, and a solitary Archaeocyathid within a calcareous band of the formation. *Hyolithes* was found at an undeterminable horizon within the formation to the south-west of the isolated outcrop of Archaeocyatha limestone about a mile east of Carrickalinga Head.

#### FORK TREE LIMESTONE

*Lower member—Archaeocyatha limestone.* Of all the Cambrian rock units in the region the outcrops of Archaeocyatha limestone occupy the largest area. The major anticline, of which the Archaeocyatha limestone is the thickest com-



petent member, is the dominant structural feature. The *Archaeocyatha* limestone unit is lithologically remarkably uniform.

The limestone is most commonly light grey to moderately dark blue on fresh surfaces. It weathers to a pale grey, nearly white or somewhat light brownish colour. It is generally a very pure, finely crystalline limestone, with more than 90 per cent. of carbonate minerals. A small amount of detrital minerals is present, quartz being the most common. It is probably dolomitized to a certain extent in various parts.

The limestone is characteristically massive and occasionally jointed.

The thickness of the unit was measured as 570 feet at Sellick Hill. In the Myponga Beach region the thickness is approximately 700 feet; in the southern part no reliable measurements can be obtained of the total thickness because of folding and faulting (in Carrickalinga Creek the observable thickness was estimated by pacing as about 380 feet). The limestone thus varies in thickness (Fig. 2), thinning to the north beyond Sellick Hill.

*Upper member—mottled limestone.* Towards the top of the Fork Tree Limestone a marked change in lithology from a massive to a mottled limestone is observed. The characteristic appearance of this mottled limestone is that of dark blue (sometimes approaching black) angular lumps of limestone surrounded by yellow-brown (sometimes reddish), somewhat more shaly material. Characteristically the distribution of the two components is highly irregular, often indicating brecciation; sometimes a degree of parallelism of the two distinct lithologies is exhibited. There is only a slight differential weathering of the two components.

The member is observed, or, in some creeks, inferred, to extend as a continuous band from north of Sellick Hill to about two miles north of Myponga Beach. The mottled limestone does not outcrop between this locality and Myponga Creek, to the south of which it continues for approximately two miles, until it is cut off by the Black Hill Fault. It reappears on the other side of the major anticline in the neighbourhood of Carrickalinga Head, truncated by the sea at its northern end and by the inferred continuation of the Black Hill Fault at its southern extremity.

The thickness of the member was measured as 38 feet on the old Sellick Hill road, and 60 feet near the coast west of Black Hill. Near Carrickalinga Head it is approximately 100 feet thick. Even though the mottled limestone is much thinner than the *Archaeocyatha* limestone, its greatly different lithology and persistence and ease of mapping justifies its separation as an upper member of the Fork Tree Limestone.

Spicules of *Chancelloria* were found in this unit at Mt. Terrible Gully. A brachiopod has also been found in the same locality by Dr. B. Daily (personal communication).

#### HEATHERDALE SHALES

This formation can be divided into two members.

*Lower member.* The top of the mottled limestone is taken as the formation boundary. In some localities the contact is marked by an abrupt change in weathering. The shales are here less resistant to leaching, and the member is found as an alternation of very friable shales and more resistant limestone. On the other hand, in other localities the lower few feet consist of highly calcareous banded rock which does not disintegrate so easily.

The shales are usually brightly coloured (red, pink), with colour banding. The beds may be sandy and sometimes (rarely) show cross-bedding on a small scale. The more or less regular dark-blue bands of limestone which alternate with these tend to be replaced by large nodules toward the top of the member.



On the old road at Sellick Hill this member does not outcrop. To the south, the mottled limestone is succeeded by a well-bedded and banded sequence of blue limestone and yellow or pink shaly limestone. Soft pink shales with blue nodules follow these. To the north of the old road similar shales immediately succeed the mottled limestone. In Mt. Terrible Gully and the next creek to the south the rocks are deeply weathered. The sequence is apparently almost completely clastic, and often sandy. There is little indication of the abundant carbonate which characterizes this horizon in other parts of the area. The uppermost few feet, especially in the creek to the south, contain numerous ovoid hollows, which obviously once contained limestone nodules.

Still further south-west (on and near the coast to the west of Black Hill) the rocks are highly calcareous. Dark blue limestone is found in bands, sometimes broken and a few centimetres thick. The shale/limestone ratio varies considerably but in the sixty feet developed in this section there is a definite but irregular upward increase in the clastic component. Large ovoid nodules then

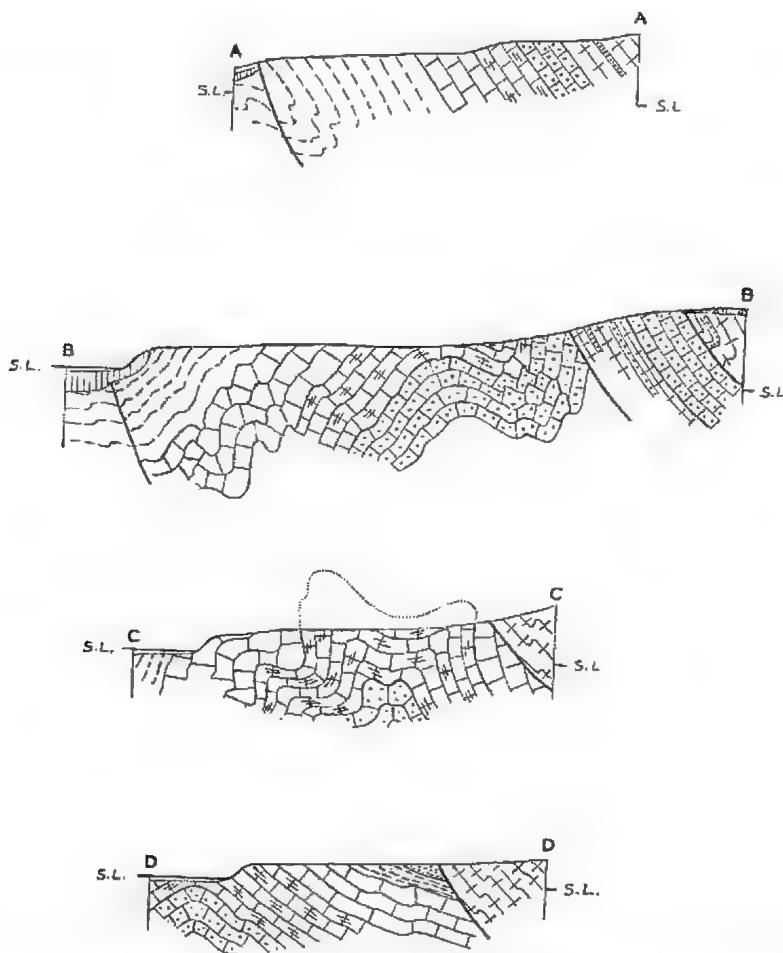
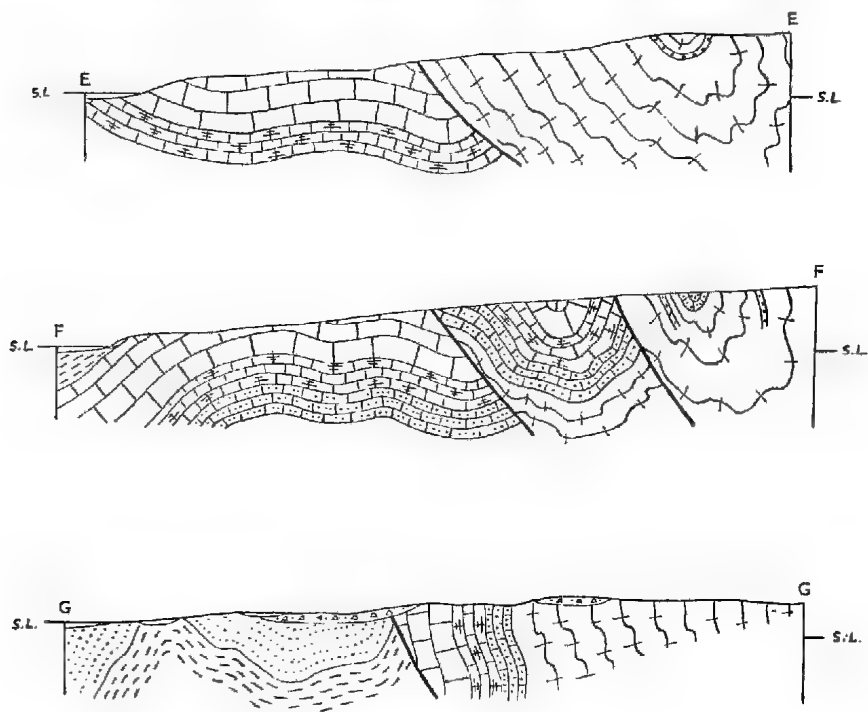


Fig. 2.—Structural sections, Sellick Hill-Carrickalinga Head. The location of each Section is shown on the map (Fig. 4). Topography accurate; vertical scale not exaggerated.



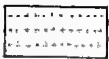
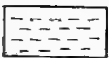
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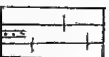
PERMIAN



CAMBRIAN

*Greywacke**Heatherdale Shale**Fork Tree Limestone**Sellick Hill Limestone**Wangkonda Formation*

PROTEROZOIC



SCALE IN CHAINS



appear and become common toward the top of the member. Many are 15 inches or more in diameter (the largest found is over 3 feet across). Distorted laminations may be traced around these nodules, although the latter sometimes show laminations. A concentric structure is seen in thin sections of the nodules which, although not phosphatic, contain quartz and some fine opaque dark material, probably organic. The nodules are arranged in rows: certain bedding planes may be traced for several yards with nodules regularly placed about six feet apart. Where well preserved the shales at the top of the member are black and occasionally pyritic. Small phosphatic nodules and elongated segregations occur in the upper part of the member.

Many of these features are found at Myponga Creek. The beds there are deeply weathered, however, and large nodules are found only in a few bands immediately below the brown shales of the upper member.

At Carrickalinga Head the member is again highly calcareous throughout. In the cliffs about one-quarter of a mile to the north there is a sequence of black rubbly limestone layers separated by black shales, with the latter deeply recessed by weathering. This rock-type is found when occurring inland, to be similar to the alternating limestone and shale bands described above. Shales with large nodules are again found above the bands, and they are pyritic when well preserved.

The member is about 250 feet thick to the south of Sellick Hill; 225 feet west of Black Hill; and about 200 feet (an estimation only) at Myponga Beach. The incompetently folded sequence at Carrickalinga Head could not be properly measured; however, the unit is thicker here than to the north.

Abundant small ribbed gastropods were found as internal and external moulds in the creek immediately south of the new road. They occur in the deeply weathered shales about fifty feet above the uppermost outcrop of *Archaeocyathia* limestone (the mottled limestone does not outcrop here). The gastropods are an undescribed species of *Heliccionella*. *Hyolithes* was found just above this level, on horizons a few inches apart. The fossils seem to be preserved largely as iron oxides, also in a deeply weathered matrix, and each bedding plane contains a large number of specimens. This indicates accumulation and sorting during the time break represented by each bedding plane. Although flattened and altered, they are rather large, and are possibly *H. planoconvexa* (Tate) (Dr. B. Daily, personal communication). *Hyolithes* is also present at the same level (approximately), north of Sellick Hill, west of Black Hill, at Carrickalinga Head (found by Dr. B. Daily), and on the coast about three-quarters of a mile to the north of the latter locality. Sponge spicules, over one cm. in length, occur in the large nodules at Carrickalinga Head.

*Upper member.* The contact between the two members is well shown west of Black Hill, and is also found at Myponga Beach and south of Sellick Hill. About five feet of shales sandwiched between the large nodules and the greywackes at Carrickalinga Head are also considered to belong to the upper member. The Heatherdale Shales cannot be subdivided sufficiently clearly, for the purposes of mapping, south of Myponga Beach.

In all cases a sudden decrease in carbonate content is evident. The contact has been mapped as being the upper limit of the occurrence of large nodules. Above this, and evidently conformable, is a uniform series of often dark, grey or brownish shales often dominated by cleavage, so that the bedding planes are difficult to detect. Small phosphatic nodules, either concentrated on certain bedding planes or scattered more uniformly, are common. Elongate inclusions of the same composition occur. In one of the sections west of Black Hill, how-

ever, large carbonate nodules are found 8 feet above the first appearance of the upper member.

Red nodules occur in this area, in a six-foot band several feet below the contact with the Tertiary limestones. These contain hematite and goyazite (determined by Dr. B. J. Skinner), as well as apatite. The black nodules, which are abundant throughout the area, have apatite, sometimes goyazite, and probably organic matter. Carbonate is lacking, as in the matrix.

Elsewhere in the region the sequence is fairly uniform. The shales are black or grey on the fresh surfaces, and apatite nodules appear at varying distances above the lower contact. The upper contact is not seen except at and to the south-west of Myponga Creek, where the member is very greatly thinned. To the north the Willunga Fault may have cut off the topmost beds, although it is possible that this is not the case (see Fig. 2). Consequent erosion of the scarp back from the fault has resulted in the covering of others by Recent outwash material. Campana and Wilson (Campana, Wilson and Whittle, 1955, p. 8) give the observable thickness of the formation as 700 feet; it is likely that the figure for the upper member alone approaches 800 feet.

The only fossil found in the upper member of the Heatherdale Shales is a flattened gastropod from north of Carrickalinga Head with a concentric structure and eccentric apex. Dr. B. Daily (personal communication) has suggested that it may be a species of *Scenella* Billings, and this seems likely.

#### GREYWACKE

In the cove north of Carrickalinga Head there are five feet of shales following the uppermost appearance of the large nodules. The rest of the sequence is an alternation of greywacke and shale, or weathered slate. Each band of greywacke seems to be a unit of deposition, usually up to five feet thick. Such units may be separated by a comparable thickness of shale, or the two greywacke units may be almost adjacent.

Several thin sections of greywacke were studied. The texture is the most noticeable feature: the angularity of the coarse component, and the presence of fine material. Quartz is the dominant mineral. The grains are in some cases more than 0.2 mm. in maximum diameter with some more than 0.5 mm.; in others the average is less, the bulk being closer to 0.1 mm. Other minerals of similar grain size include microcline, plagioclase and epidote, all varying considerably in amount. Rock fragments, of low regional metamorphic grade, are often found, as is muscovite.

The interstitial material is apparently nearly all detrital matrix, either unaltered or slightly metamorphosed since accumulation. A black component is seen, under very high power, to be opaque and fibrous. This, according to Dr. B. J. Skinner (personal communication), is almost certainly organic. Iron, perhaps in the form of goethite, accompanies this. Although the detrital matrix is very much in evidence in thin section, it tends to be wrapped around the grains, and occupies less of the total volume of rock than is evident under lower power.

The coarser components of the rock are within the sandstone range. The mainly detrital interstitial matrix is more abundant than is the case in sub-greywacke. It is concluded that the rock may best be termed a greywacke (taking the distinction between greywacke and subgreywacke as based primarily on degree of textural maturity, rather than on mineralogical grounds).

These rocks are found only in the southern part of the area, from Myponga Beach to Carrickalinga Creek. Although the greywacke units retain their shape during folding, they are very jumbled on the coast. This is evidently due to

the incompetent folding of the Heatherdale Shales against the massive crystalline limestone. Unfortunately neither group could be accurately measured, but the maximum thickness of the exposed greywacke-shale sequence is approximately 450 feet.

### PERMIAN

Unconsolidated sand and boulder clay of glacial origin cover isolated parts of the area. No detailed mapping of these subhorizontal sediments was attempted.

### TERTIARY

Bryozoal Miocene limestones rest unconformably on the Cambrian rocks at the edge of the Willunga Basin.

### QUATERNARY

Quaternary deposits in the area include coastal sand and dunes, subhorizontal alluvial clay and gravel, and kunkar.

### SOME REMARKS ON STRATIGRAPHY

#### (a) *The Precambrian*

A close resemblance has been found between the pre-fossiliferous sequence in this area and the Adelaide System of the western Mt. Lofty Ranges to the north (Campana, Wilson and Whittle, 1954, 1955). All units thin to the south, and some, such as the limestone correlated with the Brighton Limestone, disappear locally. General similarities with the type areas are seen, as in the Tapley's Hill Slates, and the Sturt Tillite.

#### (b) *The Base of the Cambrian*

As in many parts of the State, the Precambrian-Cambrian sequence is transitional. The Pound Quartzite, however, is not found. The total thickness of the massive quartzite bands of the new road or Black Hill sections is less than the known minimum thickness of the Pound Quartzite. Shales occur in greater quantity than in the Pound Quartzite, and the quartzite bands are not laterally persistent. This change in facies indicates deposition further from the source area.

The base of the *Hyalithes* sandstone is taken, for mapping purposes, as the base of the Cambrian. No fossils have been found below the Sellick Hill Limestone in the neighbourhood of Carrickalinga Creek, and there the boundary is placed at the base of the calcareous sandstone, which is equivalent to the Wangkonda Formation at Sellick Hill.

#### (c) *Correlation*

The association at Myponga Beach of *Hyalithes communis* Billings and *Helcionella tatei* Resser is referred by Daily (1956, p. 138) to his faunal assemblage No. 3, which is elsewhere characterized by the trilobite *Yorkella australis* (Woodward). *Helcionella* is a long-ranging form and the affinities of the Myponga Beach fauna could be more with assemblage No. 4, although *H. communis* is not listed here. Owing particularly to the failure to find trilobites in the Sellick Hill-Myponga region, any biostratigraphic correlation with other Cambrian rocks in South Australia must be somewhat inconclusive.

If the equivalence with assemblage 3 is valid, then the *Archaeocyatha* fauna is younger than this assemblage. This helps to elucidate certain points in connection with the Cambrian of South Australia.

Firstly, the earliest known appearance of *Archaeocyatha* on Yorke Peninsula is somewhat later than in the northern part of the State (Daily, 1956, p. 129). It is now apparent that it is still later further to the south, at Sellick Hill and Myponga Beach (assuming that, as it now seems, there are no *Archaeocyatha* in the upper member of the Wangkonda Formation).

Secondly, the White Point conglomerate of Kangaroo Island contains boulders of *Archaeocyatha* limestone. The earlier time limit for movement in the source area (whether in the formation of one or more fault scarps, or of a broad uplift), was placed after that of assemblages 1 and 2. The limestone component was transported as consolidated material. The later limit is below the upper Lower Cambrian (the Emu Bay Shale of Kangaroo Island). If the Fork Tree Limestone was developed to the west, where the movements evidently occurred, then the lower time limit could be raised to beyond assemblage 3. Recent examination by Daily of a bore core from Curramulka supports this.

Beyond the possible correlation of part of the Sellick Hill Formation with part of the Parana Limestone on Yorke Peninsula, little more can be said. The *Hyolithes* at the base of the Sellick Hill Formation is the oldest known Cambrian fossil in South Australia, if the jellyfish-bearing Round Quartzite is regarded as uppermost Precambrian.

The fauna of the lower member of the Heatherdale Shales, with *Hyolithes* (possibly *planoconvexa*) and *Helcionella* sp., is not known from this level elsewhere; neither is the gastropod ? *Scenella* Billings, from the upper member.

### STRUCTURE

The fossiliferous Cambrian formations lie on the western flank of the Myponga Hill-Little Gorge anticline, which has been shown by Campana and Wilson to dominate the structure of the region. The structural relationships of the Cambrian are shown on the tectonic sketch and in the structural sections (Fig. 2). The Cambrian is separated from the older rocks by the Black Hill Fault, except at the northern and southern ends of the region. To the north-west of the fault the attitudes of the beds are controlled mainly by the development of a series of south-west-north-east running folds, extending from south-west of Carrickalinga Hill to north of Black Hill. The tectonic sketch (Fig. 3) indicates the tendency toward development of a structure *en echelon*. It is convenient to describe the structures on either side of the Black Hill Fault separately.

At Sellick Hill and to the north-east along the Willunga Scarp the beds are overturned (Fig. 2) as first stated in print by Madigan (1927). Further south-west, near the new road, the upper member of the Wangkonda Formation may be traced over the axis of an anticline, and around onto the eastern flank of the adjacent syncline. The anticline pitches south-west, and to the north-east the stress is taken up in the contortions of the Marinoan. This axis is the first of the series. The continuity of the latter is broken by a transverse fault, about at right angles to the Black Hill Fault, one mile east of Myponga Beach.

The coastal section to the north of the transverse fault is very complicated. Above the *Archaeocyatha* limestone in the first creek north of the fault the mottled limestone is found to be repeated at least three times, as is the *Archaeocyatha* limestone, and certain pink shales and limestones. Brown and green shales outcrop in the cliffs. These may be a drag back of the upper Heatherdale member, but the lower was not recognized. Further north there is evidence of tight folding, and some indications of faulting, but it is not known how this fits into the regional structural pattern, and the area is too complex for details to be shown on the map.

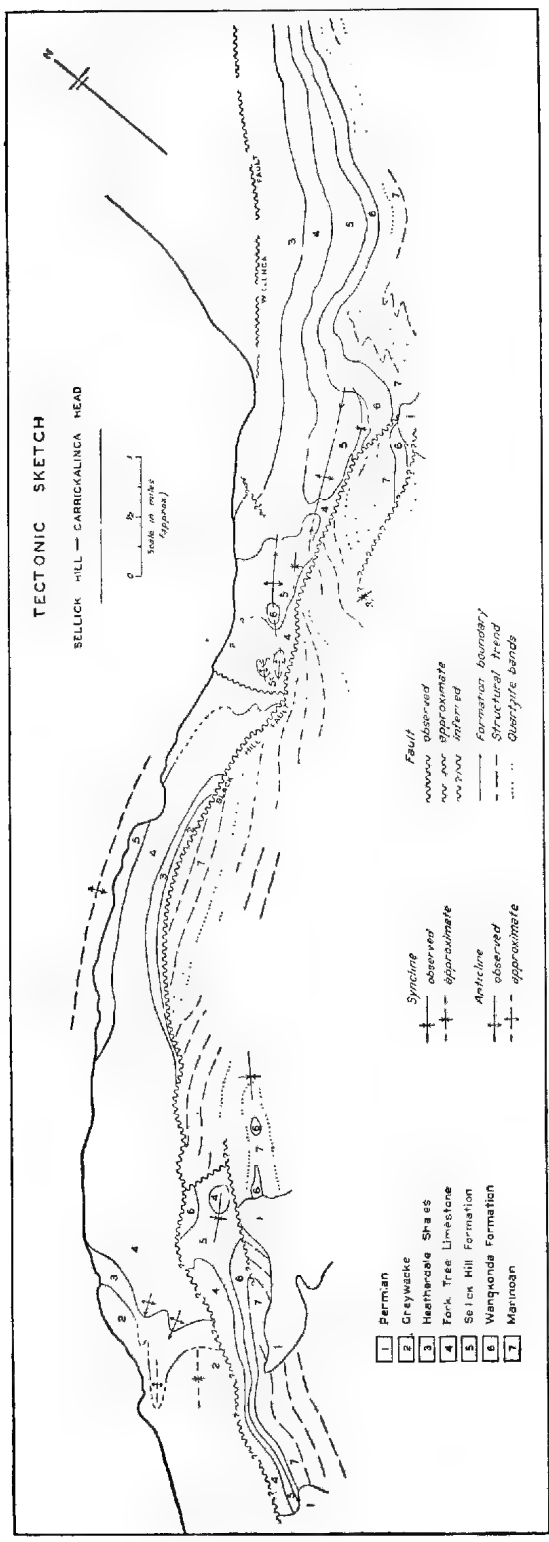


Fig. 3



The cliff sections at Myponga Beach (Fig. 2) are on the southern flank of the most persistent anticline in the series. The rocks, including the succession from the Sellick Hill Limestone to the greywacke at the top of the sequence, dip inland at successively lower angles. To the south-east the greywacke is abruptly succeeded by steeply dipping phyllitic and calcareous slates. The succession at Myponga Beach is not overturned, and it is evident that the relationship of the Cambrian to the older rocks to the south and south-east is a fault contact, not a relatively uncomplicated, although overturned, sequence through the Marinoan and Sturtian to the Torrensian basal grits and conglomerates above the Archæan, as has usually been stated or inferred in the past.

This sequence may be traced along the coast for about two miles to the south-west of Myponga Beach. Beyond this the Archæocyathia limestone only is found, and here, as over an extensive area inland, the attitude of the beds can rarely be detected. It seems fairly certain, however, that the beds are flatter than to the north, as the anticline pitches south-west. Further south the beds are cut off by the major fault, but small folds are developed to the west (Fig. 2). These small flexures inland from Carrickalinga Head are indicated in the outcrop trace of the mottled limestone. To the south, beyond the limestone, folds are inferred in the greywackes and shales.

The thick Archæocyathia limestone has dominated the structural evolution of the area: the more argillaceous units on either side show signs of relative incompetency, with contortions and drag folds near the contact. The most pronounced result of this is the apparent variation in thickness in the Heatherdale Shales at Carrickalinga Head. All the Cambrian and older limestones are recrystallized, and many show signs of stress. They have sometimes become very blocky, due to the formation of a system of joints.

Structural trends to the south-east of Black Hill Fault are shown on the tectonic sketch. Truncated cross-bedding in the sequence invariably shows the beds to be the right way up. Hence it appears that the Black Hill Fault cuts off beds successively lower in the sequence, from Black Hill to Myponga Creek. Outcropping further east up Myponga Creek, however, is a south-dipping limestone, blue or buff in colour. According to Campana and Wilson, who have mapped it, it is a "blue siliceous limestone grading in places to a buff-coloured dolomite" (Campana, Wilson and Whittle, 1955, p. 9). They correlate it with the Brighton Limestone. Still further to the east are characteristic Sturtian and Torrensian horizons, including the Sturt Tillite. It is evident that this part of the succession is overturned.

Isoclinal, synclinal folding, probably with accompanying strike faulting, is provisionally postulated, although the field evidence has not been examined in detail. The tectonic sketch shows some quartzite bands of the Black Hill area. It is somewhat diagrammatic, as there is extensive soil cover in places and it seems that the bands have been broken tectonically, but the general trends can be followed. In the creek to the south of Black Hill the quartzites on either side of the Wangkonda Formation are dipping south-east at about the same angle. The structure is considered to be a syncline, overturned toward the north-west. The southern limb is postulated as having been thrust over the other, with non-repetition of the younger beds as a result. The limits of this fault are not known: to the north-east it disappears under the Permian; to the south-west it dies out. However, the syncline may continue with a flexure toward the south. To the north of Carrickalinga Hill a syncline is indicated by the outcrop trace of quartzites, and the core contains a massive limestone correlated with the upper part of the Wangkonda Formation. Since there is a normal sequence further south in Carrickalinga Creek, a transverse fault may

separate these two localities; the significant area, however, is covered by the Permian.

Although the Black Hill Fault plane has not been observed, there is abundant evidence for its existence. Successive cutting off of beds on either side has been mentioned. This, together with the sudden change in lithology and attitude on either side, is shown on the maps. The fault is the result of an overthrust toward the north-west, and some of its effects are shown in Fig. 2. Other evidence for its existence may be found east of the new road. Campana and Wilson have mapped, beyond the Permian outlier, a straight, overturned sequence from the Cambrian to the Sturt Tillite. Assuming the Tapley Hill Slates to be equivalent to the slates to the south-east (there is no development of "Brighton Limestone"), the Sturtian is seen to be displaced. The syncline of Black Hill (Cambrian and Upper Marinoan) also continues to the south of part of the Sturtian. Tight folding, or thrusting, or both seem to have occurred. This could be an extension of the fault, as the latter is broadly arcuate in outcrop trace, and convex toward the north-west.

To the south, the fault probably extends beyond Carrickalinga Creek, but there is little field evidence for this. It is indicated, however, by the proximity of the greywacke to the Fork Tree Limestone in Carrickalinga Creek. In this area there is fossiliferous Cambrian on either side of the fault. To the west of Carrickalinga Hill the sequence from calcareous sandstone (Wangkonda Formation) to *Archaeocyatha* limestone occurs in a syncline, cut off on the north side by a transverse fault and on the east by another fault. The evidence for these includes structural discordancy and lithological discontinuity. The extent of the eastern fault to the south, toward the undisturbed sequence (from Marinoan to Fork Tree Limestone) is unknown; there is also the problem of the syncline still further to the east and its relationship to the Carrickalinga Creek section, as indicated earlier.

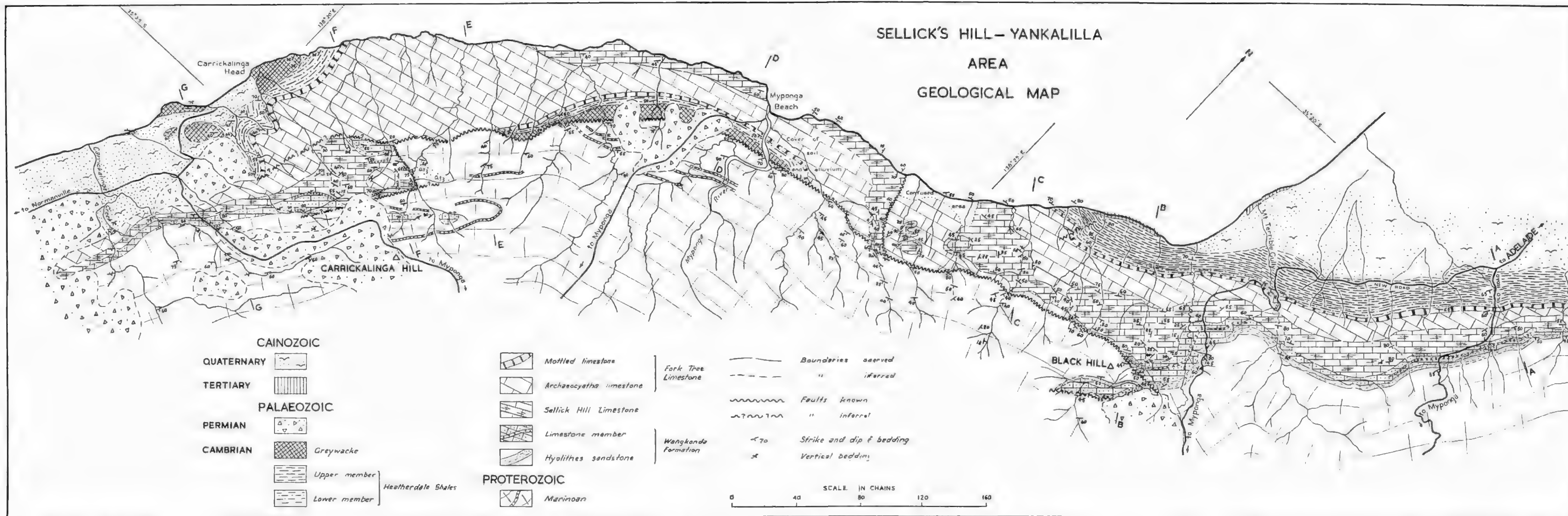
Campana, Wilson and Whittle (1955, pp. 16-17) have discussed the Willunga Fault, which has been the locus of several episodes of movement since the early Paleozoic. The fault evidently originated in the same stress field responsible for the thrusting along the Black Hill Fault plane (Fig. 2). Later movement was important in the formation and evolution of the Willunga Basin (Glaessner, 1953, text-fig. 1).

The Miocene Port Willunga Beds overly the Heatherdale Shales, having transgressed to the south-east beyond the earlier limits of the sedimentational basin (Campana, Wilson and Whittle, 1955, Pl. 1, Figs. 2, 3). These beds have been tilted steeply to the west by movement along the old fault plane (Fig. 2). The existence of late- and post-Pleistocene disturbances has been claimed by Campana and Wilson.

### SEDIMENTATION

Sedimentation in the Adelaidean geosyncline continued from late Proterozoic into Cambrian (Daily, 1956, p. 135). Rapid thinning of the Adelaide System toward the south has been interpreted by Campana and Wilson (Campana, Wilson and Whittle, 1955, p. 17) to indicate that this area was situated toward the southern limit of the sedimentational trough. Daily (1956, pp. 135, 136) has made an alternative suggestion, considering it likely that the area was a local isolated high within the geosyncline. The writers agree that the belt now occupied by the Archaean core of the Myponga Hill-Little Gorge anticline was probably mobile during the Lower Cambrian.

There are some indications of earlier mobility in this general region. The nature of the sediments described by Forbes (1957) and correlated by him with



the basal Torrensian, suggests a nearby source area of tectonic origin. A later gap in sedimentation seems indicated by the absence of the upper members of the Adelaide System to the east of the Archaean core of the Myponga Range (Campana, Wilson and Whittle, 1955, p. 17). Thinning of Proterozoic formations west of the core points to uplift in this anticlinal area. This could inhibit deposition without being important at this stage in the formation of a source area. Marinoan sedimentation in the Sellick Hill area seems to reflect the conditions present elsewhere in the State at this time. Absence of the typical Pound Quartzite may be due to non-deposition, as suggested by Daily (1956, p. 136). On the other hand the quartzites of Black Hill and to the north, not far below the *Hyolithes* sandstone, may be its stratigraphic equivalents in a somewhat different facies. There is evidence of shallow water conditions, but no breaks in deposition have so far been found.

The *Hyolithes* sandstone, with angular grains of quartz and feldspar in a partly detrital matrix, suggests transportation over a short distance. Rather than from a distant source in the west, it was more likely derived from nearby in the east. More of this material was brought in during the succeeding time of formation of the limestone member. In the north a lensing, clastic band is found within the limestone; more rounded sand grains characterize the undifferentiated Wangkonda Formation in the neighbourhood of Carrickalinga Creek.

The carbonate of the limestone member is completely recrystallized, and no evidence for the possible importance of biological activity in its deposition has been found. Any evidence of deposition as a calcarenite has also been destroyed.

Another influx of angular clastics occurred later, during the initial time of deposition of the Sellick Hill Formation. It is concluded that an area with intermittent uplift tendencies existed not far to the east.

The origin of the Sellick Hill Limestone is a puzzling, unsolved problem. No single explanation is sufficient because of the lithological and textural differences within the unit due to horizontal and vertical variation.

The cause of the most striking feature of the rock, namely, the rhythmic alternation between the shaly and the calcareous layers, is unknown. Two explanations are suggested for the pinch-and-swell structure commonly observed in the limestone bands and the relations between the laminae in the shaly parts to those in the calcareous parts as observed in thin sections. The first one postulates differential compression of the calcareous and the shaly bands respectively, probably during the subsequent tectonic disturbances. The second explanation attributes the formation of the calcareous bands to a biochemical agency, such as calcareous algae (Mawson, 1925). Variations in their rates of growth resulted in different thicknesses at different positions in the limestone bands. At the loci of rapid limestone accumulation (swells) the depositional interface was at a higher level than in the intervening depressions (pinches), where contemporaneous deposition of more shaly material took place at a slower rate. It must be emphasized that no positive proof of algal action can be produced. If any microstructure was present, it has recrystallized beyond recognition.

Although conditions of vigorous wave or current action were present at various times during the deposition of the Sellick Hill Limestone, intraformational brecciation is considered to be of restricted importance in the formation of the textural and structural features of the unit.

The Archaeocyatha limestone was deposited in an environment at sufficient distance from a source area to receive only a small amount of fine clastic material. Recrystallization of this "normal marine limestone" (Krumbein and Sloss, 1951,

p. 137) has destroyed any evidence of whether the precipitation of calcium carbonate was due to purely chemical or biochemical causes.

Archaeocyatha have been found very close to both the upper and the lower contacts, but occur in patches rather than being evenly distributed throughout the member. Contrary to the expressed opinion of several workers, the writers do not consider the term "reef" to be at all applicable to this limestone. This is particularly so when the essential reef property of active growth is considered. Archaeocyatha did not form mounds or banks in the Fork Tree Limestone. This view has already been expressed by Dailly, who says that "they [Archaeocyatha] are true biostrome organisms" (1956, p. 137). It should be mentioned, however, that Twenhofel (1950, p. 189), in his discussion of Cambrian reefs, mentions that some large accumulations of Archaeocyatha in Labrador are in the form of reefs; and Rodgers (1956, p. 375) speaks of Archaeocyatha reefs in the Lower Cambrian of the Appalachians.

The facies change from Archaeocyatha limestone to Heatherdale Shales is essentially gradational, although mappable units with fairly clear-cut boundaries are recognized within this transition. The change is one of increasing clastic deposition in an environment with a high carbonate content, with the disappearance of the benthonic Archaeocyatha at the beginning of the transition. Sedimentation again became rhythmic, although not to the same extent as before.

The origin of the large carbonate concretions is unknown. Apart from the high concentration of calcite their composition is very similar to that of the shales. Clifton (1957) has given a clear description of events to account for the growth of a nodule from a point of crystallization. He distinguishes three possible times of formation: contemporaneous (syngenetic), penecontemporaneous (shortly after deposition) and subsequent, after consolidation. That the nodules of the lower Heatherdale member are not subsequent is shown by their orientation on certain bedding planes, where the longest axis is always parallel to the bedding and the nodules are spaced over a plane. Clifton postulates a penecontemporaneous origin for the nodules of the Ohio Shale, evoking vertical compaction and the restriction of water circulation to horizontal movement, due to the impervious nature of the finely divided enclosing sediments. Thus lateral growth would tend to exceed that in a vertical direction, especially during the later stages, and large nodules would be more flattened than smaller ones. This agrees with observations at Carrickalinga Head and elsewhere. Compaction and orientation of intranodular material is suggested by horizontal laminae in the centres of the Ohio Shale concretions. The South Australian nodules have a dense fine-grained texture, but similar lamination is indicated by differential weathering on the surface. Finally, compaction restricted and stopped circulation and growth ceased. Laminae then arched over the nodules.

Such an explanation does not explain why outward growth starts from a certain favourable locus, although a penecontemporaneous origin would help to explain why nodules form instead of beds of carbonate. Thus segregation, for whatever reason, is more likely to have occurred below the depositional interface. Both nodules and beds of limestone are found in the Sellick Hill-Carrickalinga Head area, sometimes tending to alternate.

The "dark carbonaceous phyllites" of the Rapid Bay-Cape Jervis region have been considered to be the metamorphic equivalents of what are here described as the Heatherdale Shales (Campana, Wilson and Whittle, 1955, p. 8). Nodules are said to occur at the south of Campbell Creek, but their nature is not stated. These beds are described from Rapid Bay by Skinner (unpublished thesis), who does not mention any nodules. It seems most probable, then, that the beds are equivalent to the upper Heatherdale member (with small nodules, but not



nodular throughout), rather than to the shales, large nodules and limestone bands of the lower member. The latter thins out towards the north and was probably not developed above the marble of Rapid Bay. The black shales with occasional pyrite toward the top of the member at Carrickalinga Head indicate oxygen deficiency in the environment.

A break in sedimentation could have accompanied the subsequent change in environmental conditions. The upper member, which contains a few siltstones, is more clastic than the lower; there are no limestone nodules or bands; and no disseminated carbonate has been found in the shales. Thus the next phase was the accumulation of fine muds with a high phosphatic content, which concentrated to form apatite-bearing nodules and elongated segregations. Whether these formed on isochemical surfaces at or below the depositional interface is not known. The upper parts of this member, too, show some indication of the existence of a reducing environment.

The greywackes appear successively higher in the sequence from Second Valley (Campana and Wilson, 1955b, plate 6) to Myponga Beach. They were deposited intermittently as well defined units. With regard to the phosphatic shale-greywacke relationship, the alternatives are interfingering of the two units, or completion of most of the deposition of the former before the appearance of the latter.

The second alternative is favoured. Although nodules are abundant in the upper Heatherdale member, they are not found in the shales separating the greywacke units. This suggests a change in depositional environment before the advent of the coarse material.

It is therefore considered probable that the clastic fractions of the Heatherdale Shales come from the west and north-west. From the onset of greywacke deposition the poorly sorted material was introduced possibly from the opposite direction. The Myponga-Little Gorge anticline could have acted as a barrier to this material during the relatively slow accumulation of shales and limestones. The first cycle quartz and feldspar found in the earlier sediments is considered to be derived from the exposed core, but this was unimportant as a source area during greywacke sedimentation as low rank metaphoric rock fragments are common and feldspar is unimportant in the greywackes.

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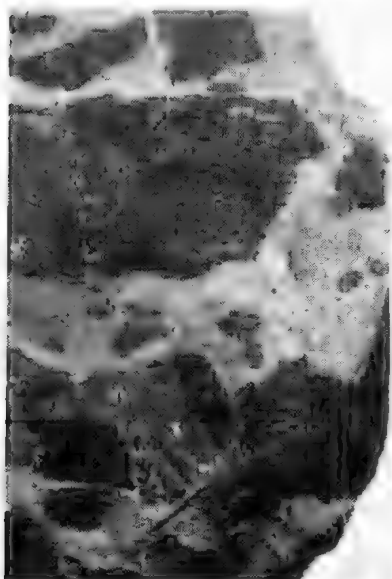
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## EXPLANATION OF PLATE 1

Scale below each figure represents 1 cm.

- Fig. 1.—Mottled limestone member of the Fork Tree Limestone. Mt. Terrible Gully. Approximately perpendicular to the bedding, which runs from left to right.
- Fig. 2.—Parallel orientation of *Hyolithes* on a bedding plane in the Sellick Hill Limestone. Myponga Beach.
- Fig. 3.—Small phosphatic nodules in the upper member of the Heatherdale Shales. Wave-cut platform 1½ miles N.W. of Black Hill.
- Fig. 4.—Sellick Hill Limestone, Sellick Hill. View perpendicular to the bedding.

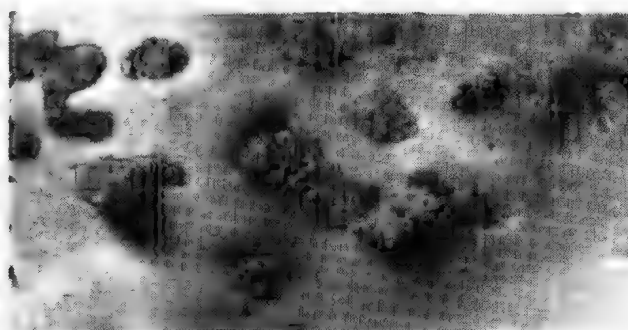




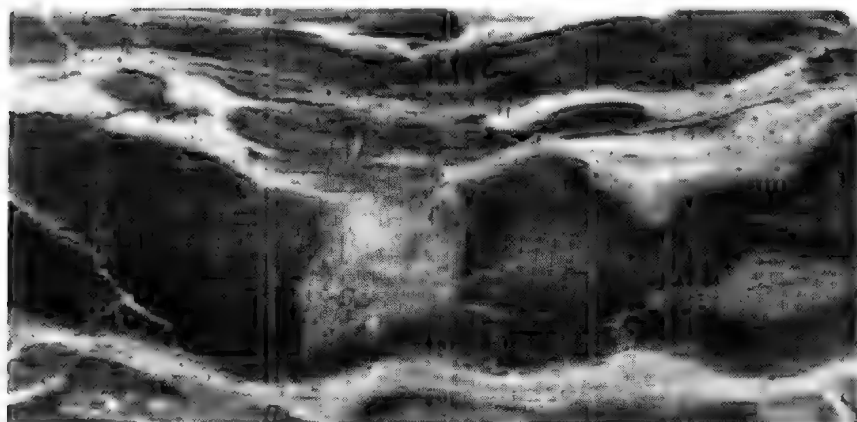
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# CHECK LIST OF CENTRAL AUSTRALIAN PLANTS

*BY G. M. CHIPPENDALE*

## Summary

The Central Australian area is delineated for the purposes of a Flora. There is brief mention of the main vegetation types, probable refuge areas, and the collection of plants within the area. A check list of the plants recorded for Central Australia is given.

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by G. M. CHIPPENDALE\*

[Read 13 November 1958]

### SUMMARY

The Central Australian area is delineated for the purposes of a Flora. There is brief mention of the main vegetation types, probable refuge areas, and the collection of plants within the area. A check list of the plants recorded for Central Australia is given.

### THE FLORA

The value of a regional flora, when published, can be gauged by its usefulness to agricultural workers, pastoralists, botanists, and other workers. A flora of an area was outlined by Bentham (1863) as "to afford the means of determining any plants in it, whether for the purpose of ulterior study or of intellectual exercise". The need for a knowledge of the plants in Central Australia, and indeed in the whole of the Northern Territory, has grown from the impetus and encouragement given the cattle industry in the Northern Territory. In particular, gaining a proper knowledge of poisonous and edible species of interest to pastoralists in Central Australia, as anywhere, means, firstly, to gain as completely as possible a knowledge of the whole flora. There is a further value in such a projected Flora of Central Australia in that it can show the true relationship with other State Floras. This can be important in providing a link between the Eastern States, South Australia and Western Australia, for the areas of these States adjacent to the Northern Territory are still little visited by botanists.

A consideration of the flora of the Northern Territory leads to the conclusion that there are at least two floristic groups, with a fairly natural boundary at the 12-inch rainfall isohyet. There is the northern "wet" country, and the central arid country. A consideration of the northern area shows the advisability of further regional divisions, such as the Barkly Tableland and related zones.

For the purpose of a Flora, Central Australia is best regarded as the area bounded east and west by the Queensland and Western Australia borders respectively, on the south by the South Australia border and on the north by the 20th parallel. Though this area can hardly be considered a distinct geographical entity, there is some great convenience in treating it as a single unit. It can be divided in turn into three broad zones. (a) the Salthush country and Spinifex sandridge country south of the Macdonnell Ranges, where the area is drained by a system of rivers, including the Hale, Todd, Finkle, Hugh, Palmer and Goyder, which flood out towards and into the Simpson Desert. Gibber plains, claypans and minor watercourses are common, with some saline lakes. (b) The mountain ranges in the centre dominated by the highly tilted and folded Macdonnell Ranges, stretching east and west from Alice Springs, and associated with the James, Waterhouse and Krischanff Ranges, and (c) the various *Acacia* scrubs, on desert sandplains, desert loams, and desert sandhills northwards from the latitude of the Macdonnell Ranges. The number of species over this Central

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\* Animal Industry Branch, Department of Territories, Alice Springs, N.T.

Australian area is not great considering it covers approximately 240,000 square miles. Botanically, the east, west and south boundaries are not good, for the plant groups at those positions extend into the adjacent States, but until botanical work can be treated on a national basis, this objection cannot be overcome satisfactorily.

There is at this time no published work on the Flora of Central Australia, for until recent years it has been little visited, and there has been no resident botanist until 1954. Ewart and Davies, "Flora of the Northern Territory" (1917), possibly fulfilled a need at that time, but it was not a true Flora, being compiled mainly of survey reports. So many Central Australian plants even known at that time were excluded, and the localities of collections of those mentioned were often vague. This latter point is, of course, not entirely due to the authors of the book. Other inaccuracies as reported by Willis (1942 and 1945) can be added to, and in fact a general lack of a true knowledge of the area make Ewart and Davies "Flora of the Northern Territory" useless today in Central Australia.

The Macdonnell-James-Krischauff Range system has in the past been shown to be an important refuge area. Here we can accept the view, as did Spencer (1921), and Cocker and Wood (1947), that species such as *Livistona mariae* F. Muell. and *Macrozamia macdonnellii* F. Muell. are undoubted relics. However, in such areas as Palm Valley, Standley Chasm, Tallaputta Gorge, and other similar places, there is still work to be done, in analysing the occurrence of many smaller plants than these two prime examples. Plants are being collected in varying seasons to get as complete as possible the record of these areas. Already many new records have been made here, and several probably undescribed species will need evaluation.

In the past there have been two tendencies with Central Australian plants. Some material occurring widely throughout Australian arid areas has been described by early authors as separate species. Other Central Australian material has been placed into species occurring elsewhere, despite morphological differences. While realising the dangers of accepting too many taxa based on regional differences, there seems to be good reasons for treating a number of taxa as subspecies, A. Lee's (1948) remarks concerning regional variants being pertinent. It is probable also, that some of the "lumped" species will show as true variants, and some varieties will be dropped. As Burbidge (1953) pointed out, it is characteristic of the inland flora "that the variations that do occur tend to be repeated through the range of distribution".

#### COLLECTION OF PLANTS

Tate's (1896) essay on Larapintine and Eremian plants was an outstanding summary of the knowledge of Central Australian plants to that time. A list of plants compiled from other collectors, including Macdouall Stuart (1860-2), Giles (1872-4), Kempe (1877-90), Tietkens (1889), and Gillen, together with those of Tate (1894) gave some reasonable localities and included a remarkable percentage of the total known species today. Since that time, the collections of G. F. Hill (1911-12) and S. A. White (1913) have added new records, and then there have been many itinerant collectors whose specimens are scattered throughout the herbaria of Australia.

Collections by J. B. Cleland, E. H. Ising, H. H. Finlayson, and some others, and J. M. Black's descriptions in the Transactions of the Royal Society of South Australia from 1909 to 1949 have been the only reliable systematic work on Central Australian plants, and these, together with the references in both edi-

tions of Black's "Flora of South Australia" have been the basis of all work on these plants. In this respect, however, there is still a great deal of work in some groups to elucidate whether Black's conception of certain species is accurate for these Central Australian plants.

In recent years, members of the Division of Land Research and Regional Survey of the C.S.I.R.O. including R. Perry, R. Winkworth, M. Lazarides, and N. Forde have contributed large collections. Members of the Animal Industry Branch of the Territories Department have collected specimens in most areas of Central Australia to build up an Herbarium at Alice Springs, and searches for some rarer species have been made, but more collections are planned to expand locality records for individual species and to obtain first-hand knowledge of little known species.

As a result of collections I have made in the last few years, the plants in the area east of the Stuart Highway to the Queensland border, but including only the fringe of the Simpson Desert, are fairly well represented. R. Crocker's collection and C. Eardley's (1946) enumeration of the species from Madigan's Simpson Desert Expedition have given a good, if not complete, record of an area still not easily accessible. West of the Stuart Highway, collections have been made in the area for about 150-200 miles, but the area of semi-desert west of the Devil's Marbles still needs investigation. Collections have been made as far as the Lake Mackay area and also along the George Gill Range and the Petermann Range, though these were in an unfavourable season.

Monographic works generally lack adequate records for Central Australian species because of the absence of collections. The impression from such monographs could be that some species are rarely, or not, represented in Central Australia, though A. Lee (1948) stated that the area was "... not so much barren of *Swainsonia* as insufficiently collected".

### CHECK LIST

The following check list has been compiled from records of historical specimens, together with the records of more recent collections, as mentioned earlier. I have been able to examine a large number of the historical specimens housed in Sydney, Melbourne and Adelaide, and these have enabled me to alter the lists of plants given for the early expeditions and to bring their nomenclature into line with more recent works. However, there are some little collected specimens as yet not examined, and these have been included. It is felt that a list of species will form a basis for work on the Flora of Central Australia, and undoubtedly there will be some changes in determinations and nomenclature in the preparation of such a work. A number of undescribed species mentioned in the list are either awaiting description by specialists at the various State Herbaria, or will be described when a better indication of their distribution is known.

Tate (1896) stated that 602 species were recorded for the Central Australia area following the Horn Expedition. This has been reduced to 510 species due to misrecords or redeterminations. 62 of these species have not been re-recorded in Central Australia to my knowledge.

Including the species listed by Eardley (1946) for the Simpson Desert Expedition, the number of species to that time was 683. Of these, 71 species are still rather rarely collected in Central Australia.

Since 1946, collectors have recorded a total of 919 species, including 156 species not listed in literature for Central Australia, but possibly some of these have been recorded in the various State Herbaria.

The total number of species, including naturalised plants, is 1101.

Naturalised plants are listed separately. Mainly, these are only found near settlements, but several have spread further, notably *Xanthium spinosum*, and *Citrullus colocynthis* and *Citrullus vulgaris*. *Sonchus oleraceus* has been found in so many localities where there is no settlement that it has been included in the main check list.

### CHECK LIST

#### PTERIDACEAE

*Gymnogramme reynoldsii* F. Muell.

#### ASPLENIACEAE

*Pleurosorus rutifolius* (R. Br.) Fee.

*Pleurosorus subglandulosus* (Hook. et Grev.) M. Tindale

#### MARSILEACEAE

*Marsilea drummondii* A. Br.

*Marsilea exarata* A. Br.

*Marsilea hirsuta* R. Br.

*Marsilea mutica* Mett.

#### POLYPODIACEAE

*Adiantum hispidulum* Swartz.

*Cheilanthes lasiophylla* Pic.-Ser.

*Cheilanthes sieberi* Kuntze

*Cheilanthes tenuifolia* (Burm.f.) Swartz.

*Cheilanthes vellea* F. Muell.

*Cyclosorus gongylodes* (Schkuhr.) Link.

*Histiopteris incisa* (Thunb.) J. Smith

*Lindsaea ensifolia* Swartz.

*Nephrolepis cordifolia* Presl.

*Pteris tremula* R. Br.

#### PSILOTACEAE

*Psilotum nudum* (L.) Grisebach

#### CYCADACEAE

*Macrozamia macdonnellii* F. Muell.

#### CUPRESSACEAE

*Callitris hugelii* (Carr.) Franco

#### TYPHACEAE

*Typha angustifolia* L.

#### POTAMOGETONACEAE

*Potamogeton tricarinatus* A. Bennett

*Ruppia maritima* L.

#### NAIADACEAE

*Najas major* All.

#### SCHEUCHZERIACEAE

*Triglochin calcitrapa* Hook.

*Triglochin centroparva* Hook.

*Triglochin hexagona* J. M. Black

#### HYDROCHARITACEAE

*Ottelia ovalifolia* (R. Br.) L. C. Rich

#### GRAMINEAE

*Amphipogon caricinus* F. Muell.

*Amphipogon caricinus* F. Muell. var. *sericeus* J. Vickery

*Aristida anthoxanthoides* (Domin) Henr.

*Aristida arenaria* Gaud.

*Aristida biglandulosa* J. M. Black

*Aristida browniana* Henr.

*Aristida capillifolia* Henr.

*Aristida inaequiglumis* Domin

*Aristida latifolia* Domin

*Aristida nitidula* (Henr.) S. T. Blake

*Aristida obscura* Henr.

*Aristida pruinosa* Domin

*Aristida ramosa* R. Br.

*Aristida strigosa* (Henr.) S. T. Blake

*Astrebula elymoides* F. Muell.

*Astrebula lappacea* (Lindl.) Domin

*Astrebula pectinata* (Lindl.) F. Muell. ex Benth.

*Bothriochloa ewartiana* (Domin)

C. E. Hubbard

*Bothriochloa intermedia* (R. Br.) A. Camus

*Brachiaria gilesii* (Benth.) Chase

*Brachiaria holosericea* (R. Br.)

Hughes

*Brachiaria miliiformis* (Presl.) Chase

*Brachiaria notochthona* (Domin)

Stapf

*Brachiaria piligera* (F. Muell.)

Hughes

*Brachiaria praetervisa* (Domin)

C. E. Hubbard

*Brachyachne ciliaris* (Benth.) C. E.

Hubbard

*Chloris acicularis* Lindl.

*Chloris pectinata* Benth.

*Chloris scariosa* F. Muell.

*Chloris virgata* Swartz.

*Chrysopogon fallax* S. T. Blake

- Chrysopogon pallidus* (R. Br.) Trin.  
 ex Steud.  
*Cymbopogon bombycinus* (R. Br.)  
 Domin  
*Cymbopogon exaltatus* (R. Br.)  
 Domin  
*Cymbopogon obtectus* S. T. Blake  
*Dactyloctenium radulans* (R. Br.)  
 Beauv.  
*Danthonia bipartita* F. Muell.  
*Dichanthium annulatum* (Forsk.)  
 Stapf  
*Dichanthium humilium* J. M. Black  
*Dichanthium sericeum* (R. Br.) A.  
 Camus  
*Digitaria ammophila* (F. Muell.)  
 Hughes  
*Digitaria brownii* (R. & S.) Hughes  
*Digitaria coenicolia* (F. Muell.)  
 Hughes  
*Digitaria ctenantha* (F. Muell.)  
 Hughes  
*Diplachne fusca* (L.) Beauv.  
*Diplachne muelleri* Benth.  
*Diplachne parviflora* (R. Br.) Benth.  
*Echinochloa turneriana* Domin.  
*Ectrosia leporina* R. Br.  
*Elytrophorus spicatus* (Willd.) A.  
 Camus  
*Enneapogon avenaceus* (Lindl.)  
 C. E. Hubbard  
*Enneapogon clelandii* N. T. Burbidge  
*Enneapogon cylindricus* N. T. Bur-  
 bidge  
*Enneapogon lindleyanus* (Domin)  
 C. E. Hubbard  
*Enneapogon oblongus* N. T. Burbidge  
*Enneapogon pallidus* (R. Br.) Beauv.  
*Enneapogon polyphyllus* (Domin)  
 N. T. Burbidge  
*Enneapogon pubescens* (Domin)  
 N. T. Burbidge  
*Eragrostis australasica* (Steud.) C. E.  
 Hubbard  
*Eragrostis barrelieri* Daveau  
*Eragrostis concinna* (R. Br.) Steud.  
*Eragrostis confertiflora* J. M. Black  
*Eragrostis cumingii* Steud.  
*Eragrostis dielsii* Pilger  
*Eragrostis elongata* (Willd.) Jacq.  
*Eragrostis eriopoda* Benth.  
*Eragrostis falcata* Gaud.  
*Eragrostis japonica* (Thunb.) Trin.  
*Eragrostis kennedyae* F. Turner  
*Eragrostis lacunaria* F. Muell. ex  
 Benth.  
*Eragrostis laniflora* Benth.  
*Eragrostis leptocarpa* Benth.  
*Eragrostis parviflora* (R. Br.) Trin.  
*Eragrostis setifolia* Nees  
*Eragrostis speciosa* (R. & S.) Steud.  
*Eragrostis xerophila* Domin  
*Eriachne aristidea* F. Muell.  
*Eriachne aristidea* F. Muell.  
*Eriachne benthamii* W. Hartley  
*Eriachne helmsii* (Domin) W. Hart-  
 ley  
*Eriachne mucronata* R. Br.  
*Eriachne nervosa* Ewart et Cookson  
*Eriachne obtusa* R. Br.  
*Eriachne pulchella* Domin  
*Eriachne scleranthoides* F. Muell.  
*Eriochloa australiensis* Stapf ex Thell.  
*Eriochloa longiflora* S. T. Blake  
*Eriochloa pseudoacrotricha* (Stapf ex  
 Thell.) C. E. Hubbard  
*Eulalia fulva* (R. Br.) O. Kuntze  
*Ichnanthus australiensis* (Domin)  
 Hughes  
*Iseilema dolotrichum* C. E. Hubbard  
*Iseilema eremaicum* S. T. Blake  
*Iseilema macrathetum* Domin  
*Iseilema membranaceum* (Lindl.)  
 Domin  
*Iseilema vaginiflorum* Domin  
*Iseilema windersii* C. E. Hubbard  
*Leptochloa digitata* (R. Br.) Domin  
*Neurachne alopecuroides* R. Br.  
*Neurachne mitchelliana* Nees  
*Neurachne muelleri* Hack.  
*Neurachne munroi* F. Muell.  
*Panicum cymbiforme* Hughes  
*Panicum decompositum* R. Br.  
*Panicum effusum* R. Br.  
*Panicum whitei* J. M. Black  
*Paractenium novae-hollandiae*  
 Beauv.  
*Paspalidium constrictum* (Domin)  
 C. E. Hubbard  
*Paspalidium rarum* (R. Br.) Hughes  
*Perotis rara* R. Br.  
*Phragmites karku* (Retz.) Trin. ex  
 Steud.  
*Plagiosetum refractum* (F. Muell.)  
 Benth.  
*Plectrachne helmsii* C. E. Hubbard



*Plectrachne pungens* (R. Br.) C. E. Hubbard  
*Plectrachne schinzii* Henr.  
*Setaria brownii* Herrm.  
*Setaria dielsii* Herrm.  
*Spathia neurosa* Ewart et Archer  
*Sporobolus actinocladius* (F. Muell.) F. Muell.  
*Sporobolus australasicus* Domin  
*Sporobolus caroli* Mez.  
*Sporobolus elongatus* R. Br.  
*Sporobolus mitchellii* (Trin.) C. E. Hubbard  
*Sporobolus* sp. nov.  
*Themeda australis* (R. Br.) Stapf  
*Themeda avenacea* (F. Muell.) Dur. et Jacks.  
*Tragus australianus* S. T. Blake  
*Triodia basedowii* F. Pritz.  
*Triodia irritans* R. Br. var. *irritans* N. T. Burbidge  
*Triodia longiceps* J. M. Black  
*Triodia pungens* R. Br.  
*Triodia spicata* N. T. Burbidge  
*Triodia* sp. nov. aff. *brizoides*  
*Triodia* sp. nov. aff. *pungens*  
*Tripogon loliiformis* (F. Muell.) C. E. Hubbard  
*Triraphis mollis* R. Br.  
*Uranthoecium truncatum* (Maid. et Betch.) Stapf  
*Zygochloa paradoxa* (R. Br.) S. T. Blake

CYPERACEAE

*Bulbostylis barbata* (Rottb.) C. B. Clarke  
*Cyperus aristatus* Rottb.  
*Cyperus bulbosus* Vahl.  
*Cyperus conicus* Boeckl.  
*Cyperus cunninghamii* (C. B. Clarke) C. A. Gardner  
*Cyperus dactylotes* Benth.  
*Cyperus difformis* L.  
*Cyperus fasciculigerus* (F. Muell.) Domin  
*Cyperus gunnii* Hook.  
*Cyperus gymnocaulos* Steud.  
*Cyperus iria* L.  
*Cyperus ixlocarpus* F. Muell.  
*Cyperus retzii* Nees  
*Cyperus rutilans* (C. B. Clarke) Maid. et Betch.  
*Cyperus vaginatus* R. Br.

*Cyperus victoriensis* C. B. Clarke  
*Cyperus* sp. nov.  
*Cyperus* sp. nov.  
*Eleocharis geniculata* (L.) R. et S.  
*Eleocharis pallens* S. T. Blake  
*Fimbristylis diphyllo* (Retz.) Vahl.  
*Fimbristylis ferruginea* Vahl.  
*Fimbristylis humilis* S. T. Blake  
*Fimbristylis oxystachya* F. Muell.  
*Fimbristylis squarrosa* Vahl.  
*Fimbristylis* sp. nov. aff. *dichotoma*  
*Fuirena glomerata* Lam.  
*Fuirena incrassata* S. T. Blake  
*Lipocarpa microcephala* (R. Br.) Kunth.  
*Scirpus littoralis* Schrad.  
*Scirpus maritimus* L.

## PALMAE

*Livistona mariae* F. Muell.

## ERIOCAULACEAE

*Eriocaulon graphitinum* F. Muell. et Tate ex Ewart et Cookson

## CENTROLEPIDACEAE

*Centrolepis polygyna* (R. Br.) Hieron

## COMMELINACEAE

*Commelina ensifolia* R. Br.  
*Commelina undulata* R. Br.

## JUNCACEAE

*Juncus* sp. nov.

## LILIACEAE

*Anguillaria dioica* R. Br.  
*Corynothecha lateriflora* (R. Br.) F. Muell.  
*Lomandra* sp. nov. aff. *dura*  
*Lomandra leucocephala* (R. Br.) Ewart var. nov.  
*Thysanotus exilisiflorus* F. Muell.  
*Thysanotus tuberosus* R. Br.  
*Xanthorrhoea thorntonii* Tate

## AMARYLLIDACEAE

*Crinum flaccidum* Herbert

## CASUARINACEAE

*Casuarina decaisneana* F. Muell.

## ULMACEAE

*Trema aspera* Bl.

## MORACEAE

*Ficus platypoda* A. Camn.

## URTICACEAE

*Parietaria debilis* Forst. f.

## PROTEACEAE

- Grevillea eriostachya* Lindl.  
*Grevillea juncifolia* Hook.  
*Grevillea nematophylla* F. Muell.  
*Grevillea refracta* R. Br.  
*Grevillea stenobotrya* F. Muell.  
*Grevillea striata* R. Br.  
*Grevillea wickhamii* Moissn.  
*Hakea chordophylla* F. Muell.  
*Hakea intermedia* Ewart et Davies  
*Hakea leucoptera* R. Br.  
*Hakea lorea* (R. Br.) R. Br.  
*Hakea macrocarpa* A. Cunn. ex R. Br.  
*Hakea multilinea* Meissn. var.  
*grammatophylla* F. Muell.  
*Hakea purpurea* Hook.  
*Hakea* sp. (possible hybrid *chordophylla* x *intermedia*)  
*Hakea* sp. (possible hybrid *intermedia* x *lorea*)  
*Hakea* sp. nov.

## LORANTHACEAE

- Amyema bifurcata* (Benth.) Tiegh.  
*Amyema gibberula* (Tate) Danser.  
*Amyema hilliana* (Blakely) Danser.  
*Amyema miquelii* (Lehm. ex Miq.) Tiegh.  
*Amyema preissii* (Miq.) Tiegh.  
*Amyema quandong* (Lindl.) Tiegh.  
*Amyema sanguinea* (F. Muell.) Danser.  
*Diplatia grandibractea* (F. Muell.) Tiegh.  
*Diplatia maidenii* (Blakely) Danser.  
*Lysiana exocarpi* (Behr. ex Schlecht.) Tiegh.  
*Lysiana exocarpi* (Behr. ex Schlecht.) Tiegh. var.  
*Lysiana murrayi* (F. Muell. et Tate) Tiegh.

## SANTALACEAE

- Anthobolus leptomerioides* F. Muell.  
*Eucarya acuminata* (R. Br.) Sprague et Summerhayes  
*Exocarpos sparticus* R. Br.  
*Santalum lanceolatum* R. Br.  
*Santalum lanceolatum* R. Br. var. *angustifolium* Benth.

## POLYGONACEAE

- Muehlenbeckia cunninghamii* (Meissn.) F. Muell.  
*Polygonum attenuatum* R. Br.

- Polygonum lapathifolium* R. Br.  
*Polygonum minus* Huds.  
*Polygonum plebeium* R. Br.  
*Rumex crystallinus* Lange

## CHENOPODIACEAE

- Arthrocnemum halocnemoides* Nees  
*Arthrocnemum leiostachyum* (Benth.) Paulsen  
*Atriplex angulata* Benth.  
*Atriplex conduplicata* F. Muell.  
*Atriplex elachophylla* F. Muell.  
*Atriplex holocarpa* F. Muell.  
*Atriplex incrassata* F. Muell.  
*Atriplex limbata* Benth.  
*Atriplex lindleyi* Moq.  
*Atriplex muelleri* Benth.  
*Atriplex nummularia* Lindl.  
*Atriplex semibaccata* R. Br.  
*Atriplex spongiosa* F. Muell.  
*Atriplex turbinata* (R. H. Anderson) Aellen  
*Atriplex velutinella* F. Muell.  
*Atriplex vesicaria* Howard ex Benth.  
*Babbagia acroptera* F. Muell. et Tate  
*Babbagia dipterocarpa* F. Muell.  
*Bassia andersonii* Ising  
*Bassia unisacanthoides* (F. Muell.) R. H. Anderson  
*Bassia bicornis* (Lindl.) F. Muell.  
*Bassia biflora* (R. Br.) F. Muell.  
*Bassia birchii* (F. Muell.) F. Muell.  
*Bassia convexula* R. H. Anderson  
*Bassia cornishiana* F. Muell.  
*Bassia costata* R. H. Anderson  
*Bassia divaricata* (R. Br.) F. Muell.  
*Bassia echinopsila* F. Muell.  
*Bassia eriacantha* (F. Muell.) R. H. Anderson  
*Bassia intricata* R. H. Anderson  
*Bassia lanicuspis* F. Muell.  
*Bassia longicuspis* F. Muell.  
*Bassia luehmanna* F. Muell.  
*Bassia paradoxa* (R. Br.) F. Muell.  
*Bassia paralleliscuspis* R. H. Anderson  
*Bassia patenticuspis* R. H. Anderson  
*Bassia sclerolaenoides* F. Muell.  
*Bassia spinosa* Ewart et Davies  
*Bassia uniflora* (R. Br.) F. Muell.  
*Bassia* sp. aff. *quinquecuspis*  
*Chenopodium antidrophyllum* Aellen  
*Chenopodium auricomum* Lindl.  
*Chenopodium cristatum* F. Muell.

*Chenopodium cristatum* x *C. melano-*  
*carpum* (possible hybrid)  
*Chenopodium melanocarpum* (J. M.  
 Black) J. M. Black  
*Chenopodium nitriaceum* (F.  
 Muell.) F. Muell. ex Benth.  
*Chenopodium rhadinostachyum*  
 F. Muell.  
*Dysphania littoralis* R. Br.  
*Dysphania plantaginella* F. Muell.  
*Dysphania simulans* F. Muell. et Tate  
*Enchylaena tomentosa* R. Br.  
*Kochia aphylla* R. Br.  
*Kochia appressa* Benth.  
*Kochia astrotricha* L. Johnson  
*Kochia brevifolia* R. Br.  
*Kochia coronata* J. M. Black  
*Kochia enchylaenoides* J. M. Black  
*Kochia georgei* Diels  
*Kochia lanosa* Lindl.  
*Kochia lobiflora* F. Muell.  
*Kochia planifolia* F. Muell.  
*Kochia scleroptera* J. M. Black  
*Kochia spongiorcarpa* F. Muell.  
*Kochia tomentosa* (Moq.) F. Muell.  
*Kochia triptera* Benth.  
*Kochia* sp. nov. aff. *spongiorcarpa*  
*Pachycornia tenuis* (Benth.) J. M.  
 Black  
*Pachycornia triandra* (F. Muell.)  
 J. M. Black  
*Rhagodia nutans* R. Br.  
*Rhagodia parabolica* R. Br.  
*Rhagodia spinescens* R. Br.  
*Salsola kali* L.  
*Salsola kali* L. var. *strobilifera* Benth.  
*Tecticornia cinerea* (F. Muell.) F. M.  
 Bail.  
*Threlkeldia inchoata* J. M. Black  
*Threlkeldia proceriflora* F. Muell.

## AMARANTHACEAE

*Achyranthes aspera* L.  
*Alternanthera angustifolia* R. Br.  
*Alternanthera denticulata* R. Br.  
*Alternanthera nana* R. Br.  
*Alternanthera nodiflora* R. Br.  
*Amaranthus grandiflorus* (J. M.  
 Black) J. M. Black  
*Amaranthus interruptus* R. Br.  
*Amaranthus mitchellii* Benth.  
*Gomphrena brownii* Moq.  
*Gomphrena* sp. aff. *brachystylis*

*Gomphrena* sp. aff. *conferta*  
*Gomphrena* sp. aff. *pusilla*  
*Ptilotus alopecuroides* (Lindl.) F.  
 Muell. var. *alopecuroides*  
*Ptilotus alopecuroides* (Lindl.) F.  
 Muell. var. *alopecuroides* forma  
*rubriflorus* (J. M. Black) Benth.  
*Ptilotus arthrolasius* F. Muell.  
*Ptilotus atriplicifolius* (A. Cunn. ex  
 Moq.) Benth.  
*Ptilotus calostachyus* (F. Muell.) F.  
 Muell.  
*Ptilotus clementii* (Försm.) Benth.  
*Ptilotus exaltatus* Nees  
*Ptilotus gaudichaudii* (Steud.) J. M.  
 Black  
*Ptilotus helipteroides* (F. Muell.) F.  
 Muell.  
*Ptilotus hoodii* F. Muell.  
*Ptilotus incanus* (R. Br.) Poir.  
*Ptilotus latifolius* R. Br.  
*Ptilotus leucocoma* (Moq.) F. Muell.  
*Ptilotus macrocephalus* (R. Br.) Poir.  
*Ptilotus murrayi* F. Muell.  
*Ptilotus nobilis* (Lindl.) F. Muell.  
*Ptilotus obovatus* (Gaud.) F. Muell.  
*Ptilotus parvifolius* F. Muell.  
*Ptilotus schwartzii* (F. Muell.) Tate  
*Ptilotus spicatus* F. Muell. ex Benth.

## NYCTAGINACEAE

*Boerhavia diffusa* L.  
*Boerhavia repanda* Willd.

## PHYTOLACACEAE

*Codonocarpus cotinifolius* (Desf.) F.  
 Muell.  
*Gyrostemon australasicus* (Moq.)  
 Heim.  
*Gyrostemon ramulosus* Desf.  
*Gyrostemon* sp. (mss. nomen C. A.  
 Gardner)

## AIZOACEAE

*Aizoon zygophylloides* F. Muell.  
*Glinus lotoides* Loefl.  
*Glinus oppositifolia* (L.) A.DC.  
*Glinus orygioides* F. Muell.  
*Mollugo cerviana* (L.) Scr.  
*Mollugo molluginis* (F. Muell.)  
 Druce  
*Trianthema australis* Melville  
*Trianthema crystallina* Vahl.  
*Trianthema crystallina* Vahl. var.  
*clavata* J. M. Black.

*Trianthema galericulata* Melville  
*Trianthema pilosa* F. Muell.

## PORTULACACEAE

*Calandrinia balonensis* Lindl.  
*Calandrinia eremaea* Ewart  
*Calandrinia polyandra* Benth.  
*Calandrinia ptychosperma* F. Muell.  
*Calandrinia pumila* F. Muell.  
*Calandrinia remota* J. M. Black  
*Calandrinia spergularina* F. Muell.  
*Calandrinia stagnensis* J. M. Black  
*Portulaca filifolia* F. Muell.  
*Portulaca intraterranea* J. M. Black  
*Portulaca oleracea* L.

## CARYOPHYLLACEAE

*Polycarpaea breviflora* F. Muell.  
*Polycarpaea corimbosa* (L.) Lam.  
*Polycarpaea involucrata* F. Muell.  
*Polycarpaea synandra* F. Muell.  
*Polycarpaea triloba* Ewart et Cookson  
*Spergularia rubra* (L.) J. et G. Presl.

## MENISPERMACEAE

*Tinospora smilacina* Benth.

## LAURACEAE

*Cassytha glabella* R. Br.

## CRUCIFERAE

*Blennodia blennodioides* (F. Muell.)  
 F. Muell.  
*Blennodia canescens* R. Br.  
*Blennodia pterosperma* J. M. Black  
*Lepidium muelleri-ferdinandi* Thell.  
*Lepidium oxytrichum* Sprague  
*Lepidium papillosum* F. Muell.  
*Lepidium rotundum* DC. (including  
 var. *phlebopetalum* (F. Muell.)  
 Maid. et Bêche)  
*Menkea sphaerocarpa* F. Muell.  
*Menkea villosula* (F. Muell. et Tate)  
 J. M. Black  
*Phlegmatospermum cochlearinum* (F.  
 Muell.) O. E. Schulz.  
*Stenopetalum lineare* R. Br. ex DC.  
*Stenopetalum nutans* F. Muell.  
*Stenopetalum velutinum* F. Muell.

## CAPPARIDACEAE

*Capparis lasiantha* R. Br.  
*Capparis mitchellii* Lindl.  
*Capparis spinosa* L.  
*Capparis umbonata* Lindl.  
*Cleome viscosa* L.

## DROSERACEAE

*Drosera burmannii* Vahl.  
*Drosera indica* L.

## CRASSULACEAE

*Crassula sieberiana* (Schultes) Druce

## PITTOSPORACEAE

*Pittosporum phyllitracoides* DC.

## ROSACEAE

*Stylobasium spathulatum* Desf.

## LEGUMINOSAE

*Aeschynomene indica* L.  
*Brachysema chambersii* (F. Muell.)  
 F. Muell. ex Benth.  
*Burtonia polyzyga* (F. Muell.) Benth.  
*Clanthus formosus* (G. Don) Ford  
 et Vickery  
*Crotalaria crispata* F. Muell. ex  
 Benth.  
*Crotalaria cunninghamii* R. Br.  
*Crotalaria dissitiflora* Benth.  
*Crotalaria dissitiflora* Benth. var.  
*rugosa* Benth.  
*Crotalaria incana* L.  
*Crotalaria linifolia* L. f.  
*Crotalaria mitchellii* Benth. var.  
*tomentosa* Ewart  
*Crotalaria novae-hollandiae* DC.  
*Crotalaria streblowii* E. Pritz.  
*Crotalaria trifoliastrum* Willd.  
*Daviesia arthropoda* F. Muell.  
*Desmodium muelleri* Benth.  
*Desmodium neurocarpum* Benth.  
*Erythrina vespertilio* Benth.  
*Gastrolobium grandiflorum* F. Muell.  
*Glycine clandestina* Wendl.  
*Glycine falcata* Benth.  
*Glycine sericea* (F. Muell.) Benth.  
*Indigofera baselowii* E. Pritz.  
*Indigofera brevidens* Benth.  
*Indigofera brevidens* Benth. var.  
*uncinata* Benth.  
*Indigofera enneaphylla* L.  
*Indigofera georgei* E. Pritz.  
*Indigofera hirsuta* L.  
*Indigofera leucotricha* E. Pritz.  
*Indigofera linifolia* Retz.  
*Indigofera monophylla* DC.  
*Indigofera parviflora* Heyne ex Wight  
 et Arn.  
*Indigofera viscosa* Lam.  
*Indigofera* sp. nov. aff. *hirsuta*

- Isotropis utropurpurea* F. Muell.  
*Isotropis wheeleri* F. Muell.  
*Isotropis winneckeana* F. Muell.  
*Jacksonia anomala* Ewart et Morrison  
*Jacksonia odontoclada* F. Muell.  
*Kennedya prorèpens* F. Muell.  
*Lotus australis* Andr. var. *exstipulatus* J. M. Black  
*Lotus coccineus* Schlecht.  
*Mirbelia viminalis* (A. Cunn.) C. A. Gardner  
*Paratephrosia lanata* (Benth.) Domin  
*Psoralea balsamica* F. Muell.  
*Psoralea cinerea* Lindl.  
*Psoralea eriantha* Benth. or sp. nov. (miss. N. T. Burbidge)  
*Psoralea leucantha* F. Muell.  
*Psoralea patens* Lindl.  
*Psoralea pustulata* F. Muell. or undescribed C. Aust. form  
*Psoralea walkingtonii* F. Muell.  
*Ptychosema unomallum* F. Muell.  
*Ptychosema stipulare* J. M. Black  
*Ptychosema trifoliolatum* F. Muell.  
*Rhynchosia australis* Benth.  
*Rhynchosia minima* (L.) DC.  
*Sesbania benthamiana* Domin  
*Swainsona beasleyana* F. Muell. subsp. *beasleyana* (F. Muell.) A. Lee  
*Swainsona burkei* F. Muell. ex Benth. subsp. *acuticarinata* A. Lee  
*Swainsona campyланtha* F. Muell.  
*Swainsona canescens* (Benth. ex Lindl.) F. Muell. var. *canescens* (Benth. apud Lindl.) A. Lee  
*Swainsona canescens* (Benth. ex Lindl.) F. Muell. var. *horniana* J. M. Black  
*Swainsona cyclocarpa* F. Muell. var. *cyclocarpa* (F. Muell.) A. Lee  
*Swainsona flavicarinata* J. M. Black  
*Swainsona microcalyx* J. M. Black subsp. *microcalyx* A. Lee  
*Swainsona microphylla* A. Gray subsp. *affinis* A. Lee  
*Swainsona microphylla* A. Gray subsp. *glabrescens* A. Lee  
*Swainsona microphylla* A. Gray subsp. *pallescens* A. Lee  
*Swainsona oligophylla* F. Muell.  
*Swainsona oroboides* F. Muell. subsp. *oroboides* (F. Muell. et Benth.) A. Lee  
*Swainsona phacoides* Benth. subsp. *phacoides* (Benth.) A. Lee  
*Swainsona rigida* J. M. Black  
*Swainsona stipularis* F. Muell. var. *genticulata* J. M. Black  
*Swainsona unifoliata* F. Muell.  
*Swainsona villosa* J. M. Black  
*Templetonia egena* (F. Muell.) Benth.  
*Templetonia hookeri* (F. Muell.) Benth.  
*Tephrosia brachycarpa* F. Muell. ex Benth.  
*Tephrosia eriocarpa* Benth.  
*Tephrosia filipes* Benth.  
*Tephrosia phaeosperma* F. Muell. ex Benth.  
*Tephrosia purpurea* Pers. sens. lat.  
*Tephrosia purpurea* Pers. var. *longifolia* Benth.  
*Tephrosia sphaerospora* F. Muell.  
*Tephrosia uniovulata* F. Muell.  
*Trigonella suavissima* Lindl.  
*Vigna lanceolata* Benth.  
*Zornia diphylla* Pers.

## MIMOSACEAE

- Acacia adsurgens* Maid. et Blakely  
*Acacia unicistocarpa* Maid. et Blakely  
*Acacia aneura* F. Muell.  
*Acacia aneura* F. Muell. var. *latifolia* J. M. Black  
*Acacia basedowii* Maiden  
*Acacia basedowii* Maiden var. *viridis* Blakely  
*Acacia brachystachya* Benth.  
*Acacia bynoeana* Benth.  
*Acacia calcicola* Forde et Ising  
*Acacia cambagei* R. T. Baker  
*Acacia collectioides* A. Cunn.  
*Acacia coriacea* DC.  
*Acacia cowleana* Tate  
*Acacia cuthbertsonii* Luehm.  
*Acacia cyperophylla* F. Muell.  
*Acacia dictyophleba* F. Muell.  
*Acacia estrophiolata* F. Muell.  
*Acacia farnesiana* Willd.  
*Acacia galioides* Benth.  
*Acacia georginae* F. M. Bail.

*Acacia hemignosta* F. Muell.  
*Acacia hilliana* Maiden  
*Acacia jennerae* Maiden  
*Acacia kempeana* F. Muell.  
*Acacia ligulata* A. Cunn. ex Benth.  
*Acacia linophylla* W. V. Fitzg.  
*Acacia lucrassenii* Domin  
*Acacia lycopodifolia* A. Cunn. ex Hook.  
*Acacia lysiphloia* F. Muell. ex Benth.  
*Acacia mangium* Willd. var. *holosericeum* (A. Cunn.) C. T. White  
*Acacia microbotrya* Benth.  
*Acacia minutifolia* F. Muell.  
*Acacia monticola* J. M. Black  
*Acacia murrayana* F. Muell. ex Benth.  
*Acacia patens* F. Muell.  
*Acacia peuce* F. Muell.  
*Acacia pyrifolia* DC.  
*Acacia ramulosa* W. V. Fitzg.  
*Acacia retivenia* F. Muell.  
*Acacia salicina* Lindl.  
*Acacia sessiliceps* F. Muell.  
*Acacia spondylophylla* F. Muell.  
*Acacia stenophylla* A. Cunn. ex Benth.  
*Acacia stipuligera* F. Muell.  
*Acacia strongylophylla* F. Muell.  
*Acacia tetragonophylla* F. Muell.  
*Acacia translucens* A. Cunn.  
*Acacia umbellata* A. Cunn. ex Benth.  
*Acacia validinervis* Maid. et Blakely  
*Acacia victoriae* Benth.  
*Acacia xylocarpa* A. Cunn. ex Benth.  
*Acacia* sp. nov. aff. *notabilis*  
*Acacia* sp. nov. aff. *oswaldii*  
*Acacia* sp. nov. aff. *signata*  
*Acacia* sp. nov. aff. *sibirica*  
*Acacia* sp. nov. aff. *doratoxylon*  
*Acacia* sp. nov. aff. *kempeana*  
*Neptunia dimorphantha* Domin  
*Neptunia dimorphantha* Domin var. *clementii* Domin  
*Neptunia gracilis* Benth.  
*Neptunia monosperma* F. Muell.

## CAESALPINIACEAE

*Cassia artemisioides* Gaud.  
*Cassia artemisioides* x *C. desolata* var. *involucrata* (presumed hybrid)  
*Cassia chatelainiana* Gaud.  
*Cassia concinna* Benth.  
*Cassia curvistyla* J. M. Black

*Cassia desolata* F. Muell.  
*Cassia desolata* F. Muell. var. *involucrata* J. M. Black  
*Cassia eremophila* A. Cunn.  
*Cassia eremophila* A. Cunn. var. *platypoda* (R. Br.) Benth.  
*Cassia eremophila* A. Cunn. var. *zygophylla* (Benth.) Benth.  
*Cassia glutinosa* DC.  
*Cassia notabilis* F. Muell.  
*Cassia oligophylla* F. Muell.  
*Cassia phyllodinea* R. Br.  
*Cassia pleurocarpa* F. Muell.  
*Cassia pruinosa* F. Muell.  
*Cassia sophora* L.  
*Cassia sturtii* R. Br.  
*Cassia venusta* F. Muell.  
*Lysiphyllum cunninghamii* (Benth.) de Wit  
*Petalostylis labicheoides* R. Br. var. *cassioides* Benth.  
*Petalostylis spinescens* E. Pritz.

## GERANIACEAE

*Erodium aureum* Carolin  
*Erodium crinitum* Carolin  
*Erodium cygnorum* Nees subsp. *cygnorum*  
*Erodium cygnorum* Nees subsp. *glandulosum* Carolin

## OXALIDACEAE

*Oxalis corniculata* L.

## ZYGOPHYLLACEAE

*Tribulus angustifolius* (R. Br.) Benth.  
*Tribulus astrocarpus* F. Muell.  
*Tribulus hystrix* R. Br.  
*Tribulus macrocarpus* F. Muell.  
*Tribulus occidentalis* R. Br.  
*Tribulus terrestris* L.  
*Zygophyllum ammophilum* F. Muell.  
*Zygophyllum apiculatum* F. Muell.  
*Zygophyllum aurantiacum* (Lindl.) F. Muell.  
*Zygophyllum compressum* J. M. Black  
*Zygophyllum glaucescens* F. Muell.  
*Zygophyllum howittii* F. Muell.  
*Zygophyllum prismatothecum* F. Muell.  
*Zygophyllum tesquorum* J. M. Black

## RUTACEAE

*Eriostemon argyreus* F. Muell. et Tate

## MELIACEAE

- Owenia acidula* F. Muell.  
*Owenia reticulata* F. Muell.

## POLYGALACEAE

- Comesperma sylvestre* Lindl.  
*Comesperma viscidulum* F. Muell.  
*Polygala chinensis* L. var. *squarrosus*  
 (Benth.) Domin

## EUPHORBIACEAE

- Adriana hookeri* (F. Muell.) Muell.-  
 Arg.  
*Euphorbia australis* Boiss.  
*Euphorbia coghlanii* F. M. Bail.  
*Euphorbia drummondii* Boiss.  
*Euphorbia eremophila* A. Cunn.  
*Euphorbia finlaysonii* J. M. Black  
*Euphorbia stevenii* F. M. Bail.  
*Euphorbia wheeleri* Baill.  
*Petalostigma quadriloculare* F. Muell.  
 var. *nigrum* Ewart et Davies  
*Phyllanthus fuernrohrii* F. Muell.  
*Phyllanthus lacunarius* F. Muell.  
*Phyllanthus rhytidospermus* F. Muell.  
*Phyllanthus thesioides* Benth.  
*Phyllanthus trachyspermus* F. Muell.  
*Sebastiania chamelazae* (L.) Muell.-  
 Arg.

## STACKHOUSIACEAE

- Macgregoria racemigera* F. Muell.  
*Stackhousia intermedia* F. M. Bail.  
*Stackhousia megaloptera* F. Muell.  
*Stackhousia viminea* Sm.

## SAPINDACEAE

- Atalaya hemiglauca* (F. Muell.)  
 F. Muell. ex Benth.  
*Diplopetis stuartii* F. Muell.  
*Dodonaea attenuata* A. Cunn.  
*Dodonaea lanceolata* F. Muell.  
*Dodonaea microzyga* F. Muell.  
*Dodonaea peduncularis* Lindl. (incl.  
 var. *coriacea* Ewart et Davies)  
*Dodonaea viscosa* (L.) Jacq. var.  
*spathulatum* (Sm.) Benth.  
*Heterodendrum floribundum* E. Pritz.  
*Heterodendrum oleifolium* Desf.

## RHAMNACEAE

- Spyridium spathulatum* (F. Muell.)  
 F. Muell. ex Benth.  
*Ventilago viminalis* Hook.

## TILIACEAE

- Corchorus elderi* F. Muell.  
*Corchorus sidioides* F. Muell.  
*Triumfetta micracantha* F. Muell.  
*Triumfetta winneckeana* F. Muell.

## MALVACEAE

- Abutilon cryptopetalum* F. Muell.  
*Abutilon fraseri* (Hook.) Hook. ex  
 Walt.  
*Abutilon leucopetalum* F. Muell.  
*Abutilon malvifolium* (Benth.) J. M.  
 Black  
*Abutilon olocarpum* F. Muell.  
*Cienfugosia gossypioides* (R. Br.)  
 Hochr.  
*Hibiscus brachychlaenus* F. Muell.  
*Hibiscus crassicalyx* J. M. Black  
*Hibiscus farragei* F. Muell.  
*Hibiscus intraterraneus* J. M. Black  
*Hibiscus krischauffianus* F. Muell.  
*Hibiscus pinonianus* Gaud.  
*Hibiscus radiatus* Cav.  
*Hibiscus sturtii* Hook.  
*Hibiscus sturtii* Hook. var. *grandiflora*  
 Benth.  
*Hibiscus sturtii* Hook. var. *muelleri*  
 Benth.  
*Hibiscus sturtii* Hook. var.  
*platychlamys* Benth.  
*Hibiscus sturtii* Hook. var. *sturtii*  
 Benth.  
*Hibiscus trionum* L.  
*Lavatera plebeia* Sims  
*Melastrium spicatum* (L.) A. Gray  
*Noloxylon australe* (Benth.)  
 Lewton  
*Noloxylon pedatum* (F. M. Bail.)  
 Lewton  
*Plagianthus glomeratus* (Hook.)  
 Benth.  
*Sida cardiophylla* F. Muell.  
*Sida corrugata* Lindl.  
*Sida corrugata* Lindl. var. *angustifolia*  
 Benth.  
*Sida corrugata* Lindl. var. *goniocarpa*  
 F. Muell.  
*Sida cryphiopetala* F. Muell.  
*Sida cunninghamii* C. T. White  
*Sida fibulifera* Lindl.  
*Sida filiformis* A. Cunn.  
*Sida intricata* F. Muell.  
*Sida lepida* F. Muell.



*Sida macropoda* F. Muell. ex Benth.  
*Sida platycalyx* F. Muell. ex Benth.  
*Sida rhombifolia* L. var. *incana* Benth.  
*Sida rohlenae* Domin  
*Sida trichopoda* F. Muell.  
*Sida virgata* Hook.  
*Sida virgata* Hook. var. *phaeotricha*  
 (F. Muell.) Benth.

## STERCULIACEAE

*Brachychiton gregorii* F. Muell.  
*Commersonia crispa* Turcz.  
*Commersonia melanopetala* F. Muell.  
*Gilesia biniflora* F. Muell.  
*Hannafordia bissillii* F. Muell.  
*Keraudrenia integrifolia* Steud.  
*Keraudrenia nephrosperma* (F.  
 Muell.) Benth.  
*Melhania incana* Heyne  
*Rulingia kenpeana* (F. Muell.) F.  
 Muell. ex J. M. Black  
*Rulingia loxophylla* F. Muell.  
*Rulingia magniflora* F. Muell.  
*Waltheria indica* L.

## DILLENIACEAE

*Hibbertia glaberrima* F. Muell.

## GUTTIFERAE

*Hypericum gramineum* Forst. f.

## ELATINACEAE

*Bergia perennis* (F. Muell.) F. Muell.  
 ex Benth.  
*Bergia truncata* Fisch. et Mey  
*Elatine gratioloides* A. Cunn.

## FRANKENIACEAE

*Frankenia connata* Sprague  
*Frankenia cordata* J. M. Black  
*Frankenia gracilis* Summerh.  
*Frankenia muscosa* J. M. Black  
*Frankenia planifolia* Sprague et  
 Summerh.  
*Frankenia serpyllifolia* Lindl.  
*Frankenia speciosa* Summerh.  
*Frankenia stuartii* Summerh.

## VIOLACEAE

*Hybanthus enneaspermus* (L.) F.  
 Muell.

## THYMELAEACEAE

*Pimelea ammodoris* F. Muell.  
*Pimelea microcephala* R. Br.  
*Pimelea trichostachya* Lindl.

## LYTHRACEAE

*Ammannia auriculata* Willd.  
*Ammannia multiflora* Roxb.  
*Rotala diandra* F. Muell.  
*Rotala verticillaris* L.

## MYRTACEAE

*Baeckea polystemona* F. Muell.  
*Callistemon viminalis* (Sol. ex  
 Gaertn.) G. Don. ex Loud. or vel.  
 aff.  
*Calytrix longiflora* F. Muell.  
*Calytrix microphylla* A. Cunn.  
*Eucalyptus aspera* F. Muell.  
*Eucalyptus brevifolia* F. Muell.  
*Eucalyptus camaldulensis* Dehnh.  
*Eucalyptus dichromophloia* F. Muell.  
*Eucalyptus dumosa* A. Cunn. ex  
 Schau.  
*Eucalyptus gamophylla* F. Muell.  
*Eucalyptus gongylocarpa* Blakely  
*Eucalyptus intertexta* R. T. Baker  
*Eucalyptus microtheca* F. Muell.  
*Eucalyptus morrisii* R. T. Baker  
*Eucalyptus normantonensis* Maiden  
 et Cabbage  
*Eucalyptus odontocarpa* F. Muell.  
*Eucalyptus oleosa* F. Muell. ex Miq.  
 var. *glauca* Maiden  
*Eucalyptus oxymitra* Blakely  
*Eucalyptus pachyphylla* F. Muell.  
*Eucalyptus papuana* F. Muell.  
*Eucalyptus pruinosa* Schau.  
*Eucalyptus sessilis* (Maiden) Blakely  
*Eucalyptus setosa* Schau.  
*Eucalyptus terminalis* F. Muell.  
*Eucalyptus thozetiana* F. Muell.  
*Eucalyptus* sp. nov. aff. *ewartianu*  
*Eucalyptus* sp. nov.  
*Melaleuca acacioides* F. Muell.  
*Melaleuca bracteata* F. Muell.  
*Melaleuca dissitiflora* F. Muell.  
*Melaleuca glomerata* F. Muell.  
*Melaleuca lasiandra* F. Muell.  
*Melaleuca linariifolia* Sm.  
*Micromyrtus flaviflora* (F. Muell.)  
 F. Muell. ex J. M. Black  
*Thryptomene maisonneuvei* F. Muell.

## HALORAGIDACEAE

*Haloragis gossei* F. Muell.  
*Haloragis heterophylla* Brongn.  
*Haloragis odontocarpa* F. Muell.

*Loudonia roei* (Endl.) Schlecht.  
*Myriophyllum verrucosum* Lindl.

#### UMBELLIFERAE

*Actinotus schwarzi* F. Muell.  
*Daucus glochidiatus* (Lab.) Fisch.  
 Mey. et Ave-Lav.  
*Hydrocotyle trichycarpa* F. Muell.  
*Trachymene gillénæ* (Tate) B. L.  
 Burt  
*Trachymene glaucifolia* (F. Muell.)  
 Benth.  
*Trachymene hemicarpa* (F. Muell.)  
 Benth.

#### EPACRIDACEAE

*Styphelia mitchellii* F. Muell.

#### PRIMULACEAE

*Samolus repens* Pers. var. nov.

#### PLUMBAGINACEAE

*Phnabago zeylanica* L.

#### OLEACEAE

*Jasminum calcareum* F. Muell.  
*Jasminum lineare* R. Br.

#### GENTIANACEAE

*Centaurium spicatum* (L.) Druce  
*Nymphodes geminata* (Griseb.) O.  
 Kuntze

#### APOCYNACEAE

*Carissa lanceolata* R. Br.

#### ASCLEPIADACEAE

*Cynanchum floribundum* R. Br.  
*Mursdenia australis* (R. Br.) Druce  
*Pentstemon kempeanu* F. Muell.  
*Pentstemon linearis* Dene.  
*Sarcostemma australe* R. Br.

#### CONVOLVULACEAE

*Bonania brevifolia* Benth.  
*Bonania rosea* (F. Muell.) Hall. f.  
*Convolvulus erubescens* Sims  
*Cuscuta australis* R. Br.  
*Evolvulus alsinoides* L. var. *villosi-*  
*calyx* v. Oeststr.  
*Ipomoea aquatica* Forsk.  
*Ipomoea costata* F. Muell.  
*Ipomoea davenportii* F. Muell.  
*Ipomoea tonchophylla* J. M. Black  
*Ipomoea muelleri* Benth.  
*Ipomoea racemigera* F. Muell. et Tate

#### BORAGINACEAE

*Cynoglossum australe* R. Br. var.  
*drummondii* Brand.  
*Halgania cyanea* Lindl.  
*Halgania cyanea* Lindl. var. *preissiana*  
 (Lehm.) Maiden et Betche  
*Halgania erecta* Ewart et Rees  
*Halgania glabra* J. M. Black  
*Halgania solanacea* F. Muell.  
*Heliotropium asperinum* R. Br.  
*Heliotropium bacciferum* Forsk.  
*Heliotropium crispatum* F. Muell. ex  
 Benth.  
*Heliotropium curassavicum* L.  
*Heliotropium diversifolium* F. Muell.  
*Heliotropium fasciculatum* R. Br.  
*Heliotropium flaginoides* Benth.  
*Heliotropium heteranthum* F. Muell.  
*Heliotropium ovalifolium* Forsk.  
*Heliotropium ovalifolium* Forsk. var.  
*gracile* R. Br.  
*Heliotropium paniculatum* R. Br.  
*Heliotropium pleiopterum* F. Muell.  
*Heliotropium strigosum* Willd. ex DC.  
*Heliotropium tenuifolium* R. Br.  
*Heliotropium tenuifolium* R. Br. var.  
*parviflorum* J. M. Black  
*Heliotropium* sp. nov. aff. *fascicu-*  
*latum*  
*Omphalolappula concava* (F. Muell.)  
 Brand.  
*Trichodesmia zeylanicum* (Burm. f.)  
 R. Br. (incl. var. *sericeum* Benth.)

#### EHRETACEAE

*Ehretia sagitta* R. Br.

#### VERBENACEAE

*Clerodendrum floribundum* R. Br.  
*Dicrastylis beveridgei* F. Muell.  
*Dicrastylis costelloi* F. M. Bail.  
*Dicrastylis doranii* F. Muell. var.  
*eriantha* F. Muell.  
*Dicrastylis exsuccosa* (F. Muell.)  
 Druce  
*Dicrastylis gilesii* F. Muell.  
*Dicrastylis lewellinii* (F. Muell.) F.  
 Muell.  
*Newcastlia bracteosa* F. Muell.  
*Newcastlia cephalantha* F. Muell.  
*Newcastlia spodioptricha* F. Muell.  
*Spartothamnella puberulus* (F.  
 Muell.) Maiden et Betche

*Spartothamnella teucriiflora* (F. Muell.) Moldenke  
*Verbena macrostachya* F. Muell.  
*Verbena officinalis* L.

## LABIATAE

*Mentha australis* R. Br.  
*Microcorys macredieana* F. Muell.  
*Plectranthus* sp. nov. aff. *parviflorus*  
*Prostanthera baxteri* A. Cunn. var. *crassifolia* Benth.  
*Prostanthera baxteri* A. Cunn. var. *sericea* J. M. Black  
*Prostanthera schultzei* F. Muell. ex Tate  
*Prostanthera striatiflora* F. Muell.  
*Prostanthera wilkieana* F. Muell.  
*Teucrium grandiusculum* F. Muell. et Tate  
*Teucrium integrifolium* F. Muell. ex Benth.  
*Teucrium racemosum* R. Br.

## SOLANACEAE

*Datura leichhardtii* F. Muell.  
*Duboisia hopwoodii* F. Muell.  
*Nicotiana benthamiana* Domin  
*Nicotiana excelsior* J. M. Black  
*Nicotiana gossei* Domin  
*Nicotiana ingulba* J. M. Black  
*Nicotiana occidentalis* H. M. Wheeler  
*Nicotiana rotundifolia* Lindl.  
*Nicotiana velutina* H. M. Wheeler  
*Solanum chenopodium* F. Muell.  
*Solanum coactiliferum* J. M. Black  
*Solanum diversiflorum* F. Muell.  
*Solanum ellipticum* R. Br.  
*Solanum eremophilum* F. Muell.  
*Solanum esuriale* Lindl.  
*Solanum ferocissimum* Lindl. or vel. aff.  
*Solanum nemophilum* F. Muell.  
*Solanum nigrum* L.  
*Solanum orbiculatum* Dun.  
*Solanum petrophilum* F. Muell.  
*Solanum phlomoides* A. Cunn. ex Benth.  
*Solanum quadriloculatum* F. Muell.  
*Solanum sturtianum* F. Muell.

## SCROPHULARIACEAE

*Adenosma coerulescens* R. Br.  
*Buchnera linearis* R. Br.  
*Elacholoma hornii* F. Muell. et Tate

*Olysanthus lobelioides* (F. Muell.) Benth.

*Limosella australis* R. Br.  
*Minulus gracilis* R. Br.  
*Morgania floribunda* Benth.  
*Morgania glabra* R. Br.  
*Morgania gracilis* R. Br.  
*Morgania pubescens* R. Br.  
*Stemodia lythrisifolia* F. Muell.  
*Stemodia viscosa* Roxb.  
*Stemodia viscosa* Roxb. var. nov.

## BIGNONIACEAE

*Pandorea doratoxylon* J. M. Black

## PEDALIACEAE

*Josephinia eugeniae* F. Muell.

## ACANTHACEAE

*Iusticia kempeana* F. Muell.  
*Iusticia procumbens* F. Muell.  
*Ruellia corynotheca* F. Muell. ex Benth.  
*Ruellia primulacea* F. Muell. ex Benth.

## MYOPORACEAE

*Eremophila battii* F. Muell.  
*Eremophila battii* F. Muell. var. *major* J. M. Black  
*Eremophila calycina* S. Moore  
*Eremophila castelli arminii* E. Pritz.  
*Eremophila christopheri* F. Muell.  
*Eremophila cordatisepalea* L. Smith  
*Eremophila duttonii* F. Muell.  
*Eremophila elderi* F. Muell.  
*Eremophila exotrichys* Kraenzl.  
*Eremophila freelingii* F. Muell.  
*Eremophila gibsonii* F. Muell.  
*Eremophila gilesii* F. Muell.  
*Eremophila gilesii* F. Muell. var. *argentea* Ewart  
*Eremophila gilesii* F. Muell. var. *filiforme* Ewart  
*Eremophila glabra* (R. Br.) Ostenf.  
*Eremophila goodwinii* F. Muell.  
*Eremophila latrobei* F. Muell.  
*Eremophila leonhardiana* E. Pritz.  
*Eremophila longifolia* (R. Br.) F. Muell.  
*Eremophila macdonnellii* F. Muell.  
*Eremophila macdonnellii* F. Muell. var. *glabriuscula* J. M. Black  
*Eremophila macdonnellii* F. Muell. var. *macrocarpa* Ewart et Davies

*Eremophila maculata* (Ker.) F. Muell.  
*Eremophila obovata* L. Smith  
*Eremophila paisleyi* F. Muell.  
*Eremophila rotundifolia* F. Muell.  
*Eremophila serrulata* (A. Cunn.) Druce  
*Eremophila strehlowii* E. Pritz.  
*Eremophila strongylophylla* F. Muell.  
*Eremophila sturtii* R. Br.  
*Eremophila willsii* F. Muell.  
*Eremophila willsti* F. Muell. var. *integrifolia* Ewart  
*Myoporum montanum* R. Br.

## PLANTAGINACEAE

*Plantago varia* R. Br.

## RUBIACEAE

*Borreria australiana* R. L. Specht  
*Borreria brachystema* (R. Br. ex Benth.) Valet  
*Canthium attenuatum* R. Br. ex Benth.  
*Canthium latifolium* F. Muell. ex Benth.  
*Canthium lineare* E. Pritz.  
*Canthium* sp. nov. aff. *lucidum*  
*Dentella asperata* Airy-Shaw  
*Dentella pulvinata* Airy-Shaw var. *repanda* Airy-Shaw  
*Oldenlandia galioides* F. Muell.  
*Oldenlandia pterospora* (F. Muell.) F. Muell.  
*Oldenlandia tillaeaceae* (F. Muell.) F. Muell.  
*Pomax umbellata* Sol.  
*Spermacoce scabra* Ewart

## CUCURBITACEAE

*Cucumis chate* Hesselq.  
*Melothria maderaspatana* (L.) Cogn.  
*Melothria micrantha* F. Muell. ex Cogn.

## CAMPANULACEAE

*Isotoma petraea* F. Muell.  
*Lobelia heterophylla* Labill.  
*Wahlenbergia sieberi* A. DC.  
*Wahlenbergia* sp. nov.  
*Wahlenbergia* sp. nov.  
*Wahlenbergia* sp. nov.  
*Wahlenbergia* sp. nov.

## GOODENIACEAE

*Calogyne berardiana* (Gaud.) F. Muell.

*Catospermum goodeniaceum* (F. Muell.) Krause  
*Dampiera candicans* F. Muell.  
*Dampiera cinerea* Ewart et Davies  
*Goodenia armitiana* F. Muell.  
*Goodenia armitiana* F. Muell. var. *multicaulis* Blakely  
*Goodenia azurea* F. Muell.  
*Goodenia basedowii* Krause  
*Goodenia cycloptera* R. Br.  
*Goodenia erecta* Ewart  
*Goodenia glabra* R. Br.  
*Goodenia glauca* F. Muell.  
*Goodenia grandiflora* Sims  
*Goodenia heterochila* F. Muell.  
*Goodenia hirsuta* F. Muell.  
*Goodenia horniana* Tate  
*Goodenia larapinta* Tate  
*Goodenia linifolia* W. V. Fitzg. ex Krause  
*Goodenia lunata* J. M. Black  
*Goodenia microptera* F. Muell.  
*Goodenia mitchelliana* Benth.  
*Goodenia mueckeana* F. Muell.  
*Goodenia ramelti* F. Muell.  
*Goodenia strangfordii* F. Muell.  
*Goodenia subintegra* F. Muell. ex J. M. Black  
*Goodenia vilmorinae* F. Muell.  
*Leschenaultia divaricata* F. Muell.  
*Leschenaultia striata* F. Muell.  
*Scaevola aemula* F. Muell.  
*Scaevola collaris* F. Muell.  
*Scaevola daleana* Blakely  
*Scaevola depauperata* R. Br.  
*Scaevola ovalifolia* R. Br.  
*Scaevola ovalifolia* R. Br. var. *glabra* R. Br.  
*Scaevola parvifolia* F. Muell. ex Benth.  
*Scaevola spinescens* R. Br.  
*Scaevola* sp. aff. *aemula*  
*Velleia connata* F. Muell.  
*Velleia paradoxa* R. Br.

## BRUNONIACEAE

*Brunonia australis* Sm.

## STYLIDIACEAE

*Stylidium floodii* F. Muell.  
*Stylidium floribundum* R. Br.  
*Stylidium inaequipetalum* J. M. Black

## COMPOSITAE

*Angianthus pusillus* Benth.  
*Bidens bipinnatus* L.

- Brachycome blackii* G. L. Davis  
*Brachycome ciliaris* (Lab.) Less. var.  
*ciliaris* G. L. Davis  
*Brachycome ciliaris* (Lab.) Less. var.  
*lanuginosa* (Steetz) Benth.  
*Brachycome iberidifolia* Benth.  
*Brachycome lineariloba* (DC.) Druce  
*Colocephalus knappii* Ewart et White  
*Colocephalus platycephalus* (F.  
 Muell.) Benth.  
*Calotis cuneifolia* R. Br.  
*Calotis cymbacantha* F. Muell.  
*Calotis erinacea* Steetz  
*Calotis hispidula* F. Muell.  
*Calotis kempei* F. Muell.  
*Calotis latiuscula* F. Muell. et Tate  
*Calotis multicaulis* (Turcz.) J. M.  
 Black  
*Calotis porphyroglossa* F. Muell. ex  
 Benth.  
*Centipeda minima* (L.) A. Br. et  
 Aschers  
*Centipeda thespidioides* F. Muell.  
*Coleocoma centaurea* F. Muell.  
*Epaltes australis* Less.  
*Flaveria australasica* Hook.  
*Glossogyne tenuifolia* (Lab.) Cass.  
*Gnaphalium japonicum* Thunb.  
*Gnaphalodes uliginosum* A. Gray  
*Gnephosis eriocarpa* (F. Muell.)  
 Benth.  
*Gnephosis gnephosioides* (F. Muell.)  
 Druce  
*Helichrysum ambiguum* Turcz.  
*Helichrysum ambiguum* Turcz. var.  
*paucisetum* J. M. Black  
*Helichrysum apiculatum* (Lab.) DC.  
*Helichrysum ayersii* F. Muell.  
*Helichrysum bracteatum* (Vent.)  
 Andr.  
*Helichrysum cassintanum* Gaud.  
*Helichrysum kempet* F. Muell.  
*Helichrysum ramossissimum* Hook.  
*Helichrysum roseum* (Lindl.) Druce  
 var. *davenportii* Benth.  
*Helichrysum semifertile* F. Muell.  
*Helichrysum thomsonii* F. Muell.  
*Helichrysum* sp. nov. aff. *ambiguum*  
*Helipterum charleyae* F. Muell.  
*Helipterum corymbiflorum* Schlecht.  
*Helipterum fitzgibbonii* F. Muell.  
*Helipterum floribundum* DC.  
*Helipterum moschatum* (A. Cunn. ex  
 DC.) Benth.  
*Helipterum pterochaetum* (F. Muell.)  
 Benth.  
*Helipterum stipitatum* (F. Muell.)  
 F. Muell.  
*Helipterum strictum* (Lindl.) Benth.  
*Helipterum tietkensii* F. Muell.  
*Helipterum* sp. nov. aff. *albicans*  
*Ixiolaena leptolepis* (DC.) Benth.  
*Millotia kempei* F. Muell.  
*Minuria cunninghamii* Benth.  
*Minuria denticulata* (DC.) Benth.  
*Minuria integerrima* (DC.) Benth.  
*Minuria leptophylla* DC.  
*Myriocephalus rudallii* (F. Muell.)  
 Benth.  
*Myriocephalus stuartii* (F. Muell. et  
 Sond.) Benth.  
*Olearia ferresii* (F. Muell.) F. Muell.  
 ex Benth.  
*Olearia stuartii* (F. Muell.) F. Muell.  
 ex Benth.  
*Olearia subspicata* (Hook.) Benth.  
*Pluchea dentex* R. Br. ex Benth.  
*Pluchea rubelliflora* (F. Muell.)  
 Druce  
*Pluchea rubelliflora* (F. Muell.)  
 Druce var. *major* Benth. ex J. M.  
 Black  
*Pluchea squarrosa* Benth.  
*Pluchea tetranthera* F. Muell. var.  
*tomentosa* Benth.  
*Podocoma cuneifolia* R. Br.  
*Podocoma* sp. nov. aff. *nana*  
*Podolepis canescens* A. Cunn. ex DC.  
*Podolepis capillaris* (Steetz) Diels  
*Podolepis georgei* Diels  
*Pterigeron adscendens* Benth.  
*Pterigeron cylindriceps* J. M. Black  
*Pterigeron decurrens* (DC.) Benth.  
*Pterigeron dentatifolius* F. Muell.  
*Pterigeron liatroides* (Turcz.) Benth.  
*Pterigeron odoratus* (F. Muell.) Benth.  
*Pterocaulon glandulosum* (F. Muell.)  
 Benth. et Hook.  
*Pterocaulon glandulosum* (F. Muell.)  
 Benth. et Hook. var. *velutinum*  
 Ewart et Davies  
*Pterocaulon sphacelatum* (Lab.) F.  
 Muell.

*Rutidosia helichrysoidea* DC.  
*Senecio gregorii* F. Muell.  
*Senecio laceratus* (F. Muell.) Bolcher  
*Senecio lautus* Sol.  
*Senecio magnificus* F. Muell.  
*Senecio odoratus* Hornemann  
*Senecio* sp. nov. aff. *cunninghamii*  
*Sigesbeckia orientalis* L.  
*Sonchus oleraceus* L.  
*Vernonia cinerea* Lees  
*Vittadinia pterochaeta* (F. Muell.)  
 J. M. Black  
*Vittadinia scabra* DC.  
*Vittadinia triloba* (Gaud.) DC.  
*Waitzia acuminata* Steetz  
*Waitzia citrina* (Benth.) Steetz  
*Wedelia asperima* (Dcne.) Benth.  
*Wedelia spilanthis* F. Muell.  
*Wedelia verbesinoides* F. Muell. ex  
 Benth.

## NATURALISED SPECIES

(In alphabetical order)

*Alternanthera pungens* H.B.K.  
*Brassica tournefortii* Gouan.  
*Carthamus lanatus* L.  
*Cenchrus ciliaris* L.  
*Citrullus colocynthis* (L.) Schrad.  
*Citrullus vulgaris* Schrad.  
*Cynodon dactylon* (L.) Pers.  
*Echinum plantaginatum* L.  
*Emex australis* Steinh  
*Erigeron floribundus* (H.B.K.)  
 Sch.Bip.  
*Malva parviflora* L.  
*Nicotiana glauca* Grah.  
*Polygonum aviculare* L.  
*Ricinus communis* L.  
*Rumex vesicarius* L.  
*Sisymbrium irysimoides* Desf.  
*Xanthium spinosum* L.

## ACKNOWLEDGMENTS

The co-operation of botanists at interstate herbaria in searches for specimens and in corrections to the list is much appreciated, as is also the action of the Directors of the Herbaria in Brisbane, Sydney, Melbourne and Adelaide in allowing me to borrow specimens.

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# **JOHN BURTON CLELAND – A TRIBUTE ON HIS EIGHTIETH BIRTHDAY**

## **Summary**



## JOHN BURTON CLELAND—A TRIBUTE ON HIS EIGHTIETH BIRTHDAY

*John Burton Cleland, the senior fellow of the Society, was born on 22nd June, 1878, and was elected to fellowship of the Royal Society of South Australia in 1895. His father, Dr. W. L. Cleland, was already a member when the Adelaide Philosophical Society became the Royal Society in 1880. J. B. Cleland has been a member of the Council of the Society at various times from 1921 until 1942 and was President in 1927-28 and again in 1940-41. He was awarded the Sir Joseph Verco medal in 1933.*

*Cleland belongs to the old tradition of the medical man who is also a naturalist. The following appreciations of his work in three fields of Natural History have been contributed by Miss C. M. Fardley, Dr. C. G. Mansford and Professor T. D. Campbell.*

### J. B. CLELAND AS A BOTANIST

Dr. J. B. Cleland's botanical activities have always been recreational and non-professional, but so well-directed, continuous and serious in their aims that his scientific achievements bear favourable comparison with those of professional botanists.

His major publication, *Toadstools and Mushrooms and Other Larger Fungi of South Australia*, Parts I and II (1934-35, Adel. Govt. Printer), was the result of his observations, collections and extensive field experience, together with long study. In scope, the work is a taxonomic textbook for South Australia, but useful beyond that State; it also contains many fine illustrations and coloured plates of great perfection, together with general chapters on the uses, edibility and poisonous nature of many of the species.

These two books are the standard reference text on toadstools and mushrooms in this State and of a high, scholarly level; they were published in the series of "Handbooks of the Flora and Fauna of South Australia", and the author is an acknowledged authority on this subject.

This is perhaps the best place to refer to Dr. Cleland's large part in the foundation of this series of Handbooks. The idea grew rather naturally out of the need felt by him, as a keen and lifelong field botanist, for a good handbook on the flora of South Australia. Many of his scientific colleagues were in a similar position with regard to other branches of local natural history and were enthusiastic about this vision of a set of Handbooks, though the work was all still to come. Dr. Cleland himself has told the story of this beginning (*Australian Herbarium News*, No. 2, March, 1948), but it will bear repeating. It goes back to 1920-21 when the South Australian Branch of the British Science Guild (no longer existing as such) was particularly interested in the wider diffusion of scientific knowledge and methods among amateurs and the general public. Cleland had already collaborated with the amateur systematic botanist, J. M. Black, and subsequently published various papers with him in these Transactions, recording collections of plants made in the more inaccessible northern and western parts of the State, as well as comprehensive censuses of southern areas, like Kangaroo Island, Monarto South and Encounter Bay especially, the perennial holiday home of his family. Black already had to his credit a small published work, *The Naturalized Flora of South Australia* (1909), and Cleland

recognised his genius for this task of preparing a flora of the native plants of the State. Cleland was instrumental in proposing to the British Science Guild that Black be invited to undertake this task; there remained the large question of publication and it was agreed that the South Australian Government might be approached on this matter.

Cleland and his colleagues could see the potential authors of other science handbooks in their immediate circle — on Mammals, Fishes and, indeed, a comprehensive list — and the proposal that was finally put before the Government by a deputation, consisting of Professor Wood Jones, Professor T. G. B. Osborn and Professor Cleland. The scientific deputation could offer a scheme for preparing and editing the volumes under the control of the South Australian Branch of the British Science Guild, with the voluntary labours of the specialist authors contributing the text — no mean offer — the scientific, educational, and economic value to agriculture and other industries was stressed. Could the Government accept this offer and in return arrange for publication by the Government Printer? The immediate reaction of the Premier, Sir Henry Barwell, as he became later, was that this was a very handsome offer; Cabinet concurred and returned a favourable reply in a fortnight, early in 1921. Since then, Handbooks have appeared in a dozen or more special fields, and they have enjoyed a high reputation. The Handbooks Committee of four or five still contains two of its original members, namely, J. B. Cleland and H. M. Hale, Editor since its inception; this is a very proud record of nearly 40 years' generous service.

Cleland was able to give J. M. Black quite expert help with the drudgery of getting such technical matter printed, because of his own familiarity with the subject. And similarly about 1940 when Black, as a man of over 80, was persuaded to undertake a Second Edition of Part I of his Flora, J. B. Cleland was the prime mover and it is due largely to his activity that arrangements were made for the completion of the Second Edition after Black's death. One has the impression that Cleland laboured almost more to promote Black's Flora than in the cause of his own Handbooks on the *Toadstools and Mushrooms*. Black's Flora in two editions of four volumes each has certainly been the most ambitious publication of the Handbook's Committee.

Cleland's knowledge of plants has its basis in the great love of an active man for outdoor life and his talent for field studies; there could not have been many weeks in his life when he failed to go for an outing or expedition. These were always occasions for collecting and noting or listing plants and always directed to the end of increasing the store of knowledge about plants in the field in Australia. He could name almost any plant at sight and could therefore quickly pick out rarities, for which he was always searching. His mental and physical energy are equally great and he has laboured continually to record observations which could be useful. Countless short papers recording local lists of plant distribution have flowed from his pen, many of these being published in the South Australian Naturalist. The memorable and frequent longer expeditions to the north of the State, and the far west and Central Australia have yielded big collections which have been faithfully worked up and published, sometimes with another botanical collaborator, usually in these Transactions. New or interesting plants were turned up quite frequently and passed on to a taxonomist, particularly J. M. Black, for description and publication; many of Black's new species were collected by Cleland, who has really acted in the capacity of a discriminating plant explorer.

Black described four new genera which are still standing and Cleland was the first collector of two of them; one was a small shrub of the family Violaceae collected in Wilpena Pound and named in 1932 after the collector — *Clelandia* —

it resembles another plant of the same family in its habit, *Hybanthus floribundus*; the other was a small annual herb of the family Boraginaceae which was published as *Embadium* in 1931, having been collected west of Lake Torrens after rains. To find unknown genera of plants in Australia at this time implies the handling of thousands of specimens and closely observant eyes.

The number of new species which came to Black via Cleland was considerable, some were named after the collector and others received the usual descriptive epithets; moreover, the literature of Australian plant taxonomy also commemorates J. B. Cleland's forbears in the matter of names.

Sets of many of his more interesting collections and rare specimens went to the Kew Herbarium; Mr. Black had whatever he needed and the rest went into Cleland's large private collection, which was only kept within reasonable proportions by giving away a large section of it periodically to one or other of the important public herbaria in Australia, especially Adelaide, where he and his interests are very well known. There were collections from successive periods of residence in Perth, Sydney, and then from 1920 Adelaide again; South Australia has certainly been the centre of most of his botanical activity, and we owe a good deal of our knowledge of the extent of distribution of individual species to his activities.

The approach to plants was also influenced by his other strong interests—medicine, anthropology, zoology and ornithology; he published papers on poison plants, with medical case histories, on drug plants used by the aborigines, on native plants eaten by animals and birds. There are also several important papers on the uses of plants by the aborigines, especially the food plants, often published in collaboration with scientific colleagues in whose company he made many anthropological expeditions. These numerous publications are a mine of information for subsequent workers and many are valuable records of a dying culture.

Cleland has made very efficient use of time; odd moments, walks and drives are regularly spent in observing plants or collecting them, and the notebook is never far-distant; when in the city and suburbs he observes introduced weeds and has regularly furnished an exhibit of fresh named weeds to the South Australian Museum during recent years; if a plant has escaped or become naturalized, he is generally among the first to record or notice it, for he has travelled widely and constantly about the State.

Cleland has made his mark as one who has loved and filled his leisure with the study of Australian plants, especially in the field, to such a degree that science has received much benefit, and also as one who has conceived great plans for the advance of systematic Botany in Australia and who has not spared himself in assisting to carry them out.

C.M.E.

#### J. B. CLELAND AS A MYCOLOGIST

During the past half-century J. B. Cleland has been a most assiduous collector of Australian Fungi, and has accumulated what is undoubtedly the most extensive herbarium of these in existence. His main collecting grounds have been New South Wales and South Australia, but on his journeys around Australia and abroad, he has supplemented his collections with specimens from other parts of the continent, from New Zealand, North America and Europe. In addition, he has received many named specimens of foreign fungi in exchange for his own from Australia.

Cleland has been unique as an Australian collector of fungi, in that he has paid particular attention to the larger fungi, especially the Agaricales, which

have been almost totally neglected since the appearance of Cooke's Handbook of Australian Fungi (1892), a work which was very unsatisfactory and even misleading. Cleland, with the assistance of E. Cheel of Sydney, and of other specialists in various groups of the fungi, published the results of his collections in New South Wales in a series of papers from 1914 to about 1925, and on his return to the University of Adelaide, continued the collection of the fungi of South Australia. His results on the latter were gathered into his monograph, *The Trudstoos and Mushrooms of South Australia*, in 1934, since when a few additional species have been published. This monograph represents the only major work on the Agaricales of Australia to appear since 1892; unfortunately, it has not been followed up by similar accounts of these fungi in the other States of the Continent, so even today we have little or no data on the distribution of individual species in Australia, nor any general picture of the agaric flora here.

Since 1934, a new system of classification of the Agaricales has been developed outside Australia, largely as a result of the investigations of Dr. R. Singer; the older "Friesian" classification was based mainly on macroscopic characters, gradually supplemented by microscopic details of spores, cystidia and other organs of the fructifications. The newer classification is fundamentally different, being based primarily upon details of the microscopic structure of the fruit bodies, and has resulted in the amalgamation of many of the older "genera" and the segregation of others into separate new genera. Hitherto no specialist has arisen in Australia to apply this new classification to our agarics, and at present such work is most urgently needed, before the accumulation of specimens and "species" becomes too great for a single specialist to attempt to sort out. Unfortunately, such a work requires the services of a specialist familiar with similar fungi in other parts of the world and thus capable of pronouncing with some degree of certainty whether the specimens encountered here are identical with species recorded elsewhere. This necessitates examination of living material of each species and variety in the field, followed by relation to existing herbarium specimens; only after such study can the latter be utilised as the basis for specific and varietal names. Recent attempts to induce Dr. Singer himself to come to Australia and undertake this work proved unsuccessful, and the whole study of Australian Agaricales must remain in abeyance until he or some similar specialist arrives.

The Cleland specimens are particularly valuable in that a complete description of macroscopic characters is included with each, and there is no doubt that eventually this herbarium will form the foundation collection of Australian agarics, a position similar to the Friesian herbarium in Europe. The material exists, coupled with all information at present available on each specimen; it now needs working through in the light of modern concepts of classification and specific determination. There is no doubt in the present writer's mind that most, if not all, the new species and varieties described by Cleland and his co-workers from his specimens will stand in the future, though complete new descriptions of each will be necessary to include details of microscopic structure. On the other hand, it is doubtful whether many of the European and American specific names attached to the remaining specimens will stand close examination, there is a good deal of reason to suspect that these specimens differ materially from their relatives in other countries, and they may have to be described as new species or varieties.

J. B. Cleland has generously donated the entire collection of some groups to the Plant Pathology Herbarium of the Waite Institute, Adelaide, which now houses the following:

*Lichens.* Unfortunately, it has not yet proved possible to locate any specialist in this group willing to undertake the determination of the 1,500 specimens of the collection. Hitherto, in Australia there are records of over a thousand species and varieties, based mainly on collections made in 1890-1910 in Queensland and Victoria. It is probable that the Cleland specimens include many new records for the Australian Lichen Flora.

*Gasteromycetes.* The Cleland specimens were revised by Dr. G. H. Cunningham and included in his book, *The Gasteromycetes of New Zealand and Australia*, though further collections have been made since this appeared. The specimens of *Tulostoma* are now under further revision by Dr. Jorge Wright of Argentina, in connection with a new world monograph of this genus.

*Discomycetes.* The whole Cleland collection of this group is now being worked out by Dr. Dennis of Kew; it is probable that many of the existing records of Australian species are inexact.

*Clavariaceae.* The new classification of this family dates from Corner's monograph (1950); Mrs. Womersley, a former student of Corner, has commenced working out the Cleland specimens.

*Myxomycetes.* These have now been determined by the present writer from Lister's monograph.

*Polyporaceae, Thelephoraceae, etc.* The Cleland specimens at present in the Waite Institute comprise mainly the foreign specimens he received as exchanges; his own Australian specimens are still in his own charge; they will require very detailed revision in the light of Cunningham's work on the New Zealand specimens; this has involved what is virtually a completely new classification of these families, based upon microscopic structure. The revision of Australian specimens can only be undertaken by a specialist, and it is to be hoped that Dr. Cunningham himself may find time to undertake this work.

C.G.H.

#### J. B. CLELAND AND ANTHROPOLOGY

The interest of J. B. Cleland in the natural history of man and, in particular, of the Australian aboriginal, was probably stimulated during his boyhood through his father's professional association with the Parkside Mental Hospital and the aboriginal inmates of that institution.

With his maturer interest in natural history, it was inevitable that he became one of the enthusiastic members of the University staff who joined in the local revival of interest in Australian anthropology, stimulated by the presence here of the late Professor Wood Jones.

Cleland was one of the University party who accompanied Professor Clark Wissler and Mr. Edward Embree (of the Rockefeller Foundation) on a visit to Wilgena, in the far north-west of South Australia in 1925. These two American visitors were here in connection with the proposed establishment of an Australian School of Anthropology. The visit to Wilgena gave the Americans their first acquaintance with aboriginal life and no doubt stimulated their interest in Australian anthropology.

From then onwards, Adelaide University field studies on aboriginal life — revived after the long past work of Sir Edward Stirling — became almost annual events. In all this activity, Cleland was among the earliest workers. To promote these studies, a Board for Anthropological Research was formed in 1927. For several years the late Dr. W. Ray was Chairman; but in 1930 Cleland became its Chairman, a position he has held up to the present time.

The first of these Central Australian major field expeditions was in 1927, with visits to Mucumba and Alice Springs; and Cleland was a member of that



first project. In the following years, he maintained his active participation in many expeditions to the outback of Central and South Australia. In 1928, to Koonibba; 1929, Hermannsburg; 1930, Macdonald Downs; 1931, Cockatoo Creek; 1932, Mt. Liebig; 1933, Ernabella; 1934, Diamantina; 1936, Granites; 1937, Nepabunna; 1939, Ooldea.

During the period prior to World War II, Cleland accompanied several minor excursions to more accessible native Settlements in South Australia.

Since the War, field expeditions to Central Australia were revived in 1951, and Cleland still continued his active work among the natives at Yuendumu; with earlier visits to Haasts Bluff and Aryonga Settlements.

All these activities were not enough to absorb all of Cleland's enthusiasm. He was among the foundation members of the Anthropological Society of South Australia, founded in 1925. He occupied the position of President for three sessions and has been almost continuously a member of its council throughout the history of the Society. For a number of years he was a member of the State Aborigines Advisory Council. In 1939 a new Aboriginal Act was passed; and in 1940, the Aborigines Protection Board was constituted. For eighteen years he has been Deputy to the Minister's Chairmanship of this Board and has given valuable and unremitting service in its duties. The functions of the Board have necessitated many visits of inspection to the far outback of the State. Cleland has been untiring in these arduous excursions; and his well-maintained physical energy was evidenced on one occasion in relatively recent years when visiting Ernabella Settlement in the Musgrave Ranges; he was one of a small band of enthusiasts who climbed to the summit of Mt. Woodroffe — the highest peak in South Australia.

From all this wide and varied experience, Cleland has placed many of his observations on permanent record in a long list of valuable publications. These are too numerous to list in detail; but altogether they make an outstanding contribution to the ecology of the Australian aboriginal. To mention only some of his major works, these have dealt with: diseases of the natives; his pioneer investigations in blood grouping; indigenous plants as native food materials; and his remarkable story of the aboriginal's discovery of the properties and uses of the plants *Nicotiana* and *Duboisia*, is a subject far more fascinating historically and scientifically than the traditional romance of Sir Walter Raleigh and tobacco.

Just as impressive as Cleland's extensive experience and unbounded enthusiasm in these anthropological studies, has been his sincere interest and affection for the aboriginal as a human being. His studies and interest in these native folk will long remain as one of the fitting memorials to a lifetime of faithful service to science and his State.

T.D.C.

**LIST OF LECTURES GIVEN AT MEETINGS DURING THE  
YEAR 1957-58.**

**Summary**



**LIST OF LECTURES GIVEN AT MEETINGS DURING THE  
YEAR 1957-58.**

- Oct., 1957. Presidential Address by Mr. I. M. THOMAS: "The Evolution of the Thyroid".
- Nov., 1957. Mr. J. SILSBURY, Dept. of Agronomy, Waite Institute: "Some Aspects of the Ecology and Distribution of the Genus *Kennedya* (Leguminosae) in Western Australia".
- April, 1958. DR. M. F. GLAESSNER, Dept. of Geology, University of Adelaide: "The Oldest Fossils of South Australia".
- May, 1958. PROFESSOR R. K. MORTON, Dept. of Agricultural Chemistry, Waite Institute: "The Fine Structure of Cells in Relation to Biological Activity".
- June, 1958. DR. W. G. ELFORD, Lecturer in Physics, University of Adelaide: "Artificial Earth Satellites".
- July, 1958. MR. J. C. FORNACHON, Director of Research, Australian Wine Research Institute: "The Organisation, Function and Programme of the Wine Research Institute".
- Sept., 1958. DR. F. W. WOOD, Superintendent of Range Development, Weapons Research Establishment: "The International Geophysical Year".

**BALANCE SHEET**

**Summary**

# ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED)

Receipts and Payments for year ended 30th September, 1958.

	£	s.	d.		£	s.	d.
To Balance 1/10/57	1,453	15	0	By Printing and Publishing Volume 81,			
" Subscriptions	296	7	10	Reprints, etc.	1,439	6	1
" Government Grant	1,775	0	0	" Library Assistants	107	0	1
" Sale of Publications, etc.	352	8	6	" Printing and Stationery	129	18	
" Interest—				" Postages, Duty Stamps, etc.	78	0	
Endowment Fund	£229	19	3	" Cleaning	58	7	
Savings Bank of				" Insurance	58	1	
S.A.	51	1	9	" Lighting	6	10	
	281	1	0	" Binding Volumes	1,175	19	
				" Shelving	114	1	
				" Packing Transactions	41	16	
				" Vacuum Cleaner	21	9	1
				" Periodicals, etc.	14	10	
				" Cartage	5	3	
				" Sundries	9	7	
				" Balance—			
				Savings Bank of			
				S.A., Rundle St.	£914	7	9
				Less outstanding			
				cheques	15	9	4
					898	18	
	£4,158	12	4		£4,158	12	

Audited and found correct.

Adelaide, 1st October, 1958.

N. S. ANGEL, A.U.A. Com. } Hon.  
F. M. ANGEL } Auditors

## ENDOWMENT FUND

Receipts and Payments for year ended 30th September, 1958 .

	£	s.	d.		£	s.	d.
To Balance 1/10/1957	6,110	0	0	By Revenue A/c.	229	19	
" Interest—				" Balance—			
Inscribed Stock	£224	9	3	C'wealth Inscribed			
Gas Co.	5	10	0	Stock	£6,010	0	0
	229	19	3	S.A. Gas Co.			
				Bonds	100	0	0
					6,110	0	
	£6,339	19	3		£6,339	19	

Audited and found correct. The Stock and Bond have been verified by certificates from the respective institutions.

F. M. ANGEL } Hon.  
N. S. ANGEL, A.U.A. Com. } Auditors

Adelaide, 1st October, 1958.

H. WOMERSLEY, Hon. Treasurer.

# **AWARDS OF THE SIR JOSEPH VERCO MEDAL**

## **Summary**

## AWARDS OF THE SIR JOSEPH VERCO MEDAL

1929	PROF. WALTER HOWCHIN, F.C.S.
1930	JOHN MCC. BLACK, A.L.S.
1931	PROF. SIR DOUGLAS MAWSON, O.B.E., D.Sc., B.E., F.R.S.
1933	PROF. J. BURTON CLELAND, M.D.
1935	PROF. T. HARVEY JOHNSTON, M.A., D.Sc.
1938	PROF. J. A. PRESCOTT, D.Sc., F.A.C.I.
1943	HERBERT WOMERSLEY, A.L.S., F.R.E.S.
1944	PROF. J. G. WOOD, D.Sc., Ph.D.
1945	CECIL T. MADIGAN, M.A., B.E., D.Sc., F.G.S.
1946	HERBERT M. HALE, O.B.E.
1955	L. KEITH WARD, I.S.O., B.A., B.E., D.Sc.
1956	N. B. TINDALE, B.Sc.
1957	C. S. PIPER, D.Sc.

## LIST OF FELLOWS

AS AT 30th SEPTEMBER, 1958.

Those marked with an asterick (\*) have contributed papers published in the Society's Transactions. Those marked with a dagger (†) are Life Members.

Any change in address or any other changes should be notified to the Secretary.

*Note*.—The publications of the Society are not sent to those members whose subscriptions are in arrears.

Date of Election	Date of Honorary Election	HONORARY FELLOWS
1935	1949	*CLELAND, PROF. J. B., M.D., Dashwood Road, Beaumont, S.A.— <i>Verco Medal</i> , 1933; <i>Council</i> , 1921-26, 1932-37; <i>President</i> , 1927-28, 1940-41; <i>Vice-President</i> , 1926-27, 1941-42.
1905	1955	*MAWSON, PROF. SIR DOUGLAS, O.B.E., D.Sc., B.E., F.R.S., University of Adelaide— <i>Verco Medal</i> , 1931; <i>President</i> , 1924-25, 1944-45; <i>Vice-President</i> , 1924-25, 1925-26; <i>Council</i> , 1941-43. (Sir Douglas Mawson died on 14th October, 1958.)
1913	1955	*OSBORN, PROF. T. G. B., D.Sc., St. Mark's College, Pennington Terrace, North Adelaide— <i>Council</i> , 1915-20, 1922-21; <i>President</i> , 1925-26; <i>Vice-President</i> , 1924-25, 1926-27.
1912	1955	*WARD, L. K., I.S.O., B.A., B.E., D.Sc., 22 Northumberland Street, Heathpool, Marryatville, S.A.— <i>Council</i> , 1924-27, 1933-35; <i>Vice-President</i> , 1927-28; <i>President</i> , 1928-30.

Date of Election	FELLOWS
1946.	ABBIE, PROF. A. A., M.D., D.Sc., Ph.D., University of Adelaide.
1958.	ABELE, K., Dr. Phil. (Marburg), Dr.Phil.Nat. (Tartu-Dorpat), M.Sc. (Riga), 42 Kildonan Road, Warradale Park, S.A.
1953.	ADCOCK, MISS A., 4 Gertrude Street, Norwood, S.A.
1927.	*ALDERMAN, PROF. A. R., Ph.D., D.Sc., F.G.S., Department of Geology, University of Adelaide— <i>Council</i> , 1937-42, 1954-57.
1951.	ANDERSON, MRS. S. H., B.Sc., 31 Lakenian Street, North Adelaide.
1935.	*ANDREWARTHA, H. C., M.Ag.Sc., D.Sc., Zoology Dept., University of Adelaide— <i>Council</i> , 1949-50; <i>Vice-President</i> , 1950-51, 1952-53; <i>President</i> , 1951-52.
1935.	*ANDREWARTHA, MRS. H. V., B.Agr.Sc., M.Sc. (nee H. V. Steele), 29 Claremont Avenue, Netherby, S.A.
1929.	*ANGEL, F. M., 34 Fullarton Road, Parkside, S.A.
1939.	*ANGEL, MISS L. M., M.Sc., c/o Mrs. C. Angel, 2 Moore Street, Toorak, Adelaide, S.A.
1945.	*BARTLETT, H. K., L.Th., 2 Abbotshall Road, Lower Mitcham, S.A.
1950.	BECK, R. G., B.Agr.Sc., R.D.A., Lynewood Park, Mil-Lal, via Mount Gambier, S.A.
1932.	BEGG, P. R., D.D.Sc., L.D.S., Shell House, 170 North Terrace, Adelaide.
1928.	BEST, R. J., D.Sc., F.A.C.I., Waite Institute (Private Mail Bag), Adelaide.
1956.	BLACK, A. B., A.S.A.S.M., M.I.M.M., 36 Woodcroft Avenue, St. Georges, S.A.
1934.	BLACK, E. C., M.B., B.S., Magill Road, Tranmere, Adelaide.
1950.	BONNIN, N. J., M.B., B.S., F.R.C.S. (Eng.), F.R.A.C.S., 40 Barnard Street, North Adelaide, S.A.
1945.	†*BONYTHON, C. W., B.Sc., A.A.C.I., Romalo House, Romalo Avenue, Magill, S.A.
1940.	BONYTHON, SIR J. LAVINGTON, 263 East Terrace, Adelaide.
1945.	*BOOMSMA, C. D., M.Sc., B.Sc.For., 6 Celtic Avenue, South Road Park, S.A.

Date of  
Election

1957. \*BROOKES, Miss H. M., Waite Institute (Private Mail Bag, No. 1), Adelaide.  
 1939. BROOKMAN, Mrs. R. D. (nee A. Harvey), B.A., Meadows, S.A.  
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